FIELD, LABORATORY, AND LIBRARY MANUAL

IN

PHYSICAL GEOGRAPHY

BY

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PREFACE

In offering this manual to the public the author wishes to express the hope that it may prove helpful to his fellow-teachers, and that teachers and pupils alike may get from it at least a portion of the pleasure that he has taken in working out its exercises. The manual consists of readings and exercises selected from those which he has used in his own classes in the high school. He hopes that they may be of value in guiding others in their first attempts at scientific investigation and research.

Physical geography gives the student a broader outlook than any other science in the curriculum of secondary schools. It is a proper culmination of the nature study of the grammar school, and an appropriate introduction to the more technical and rigid sciences of the high school. Its value arises in part from the fact that it "touches nature" in so many places. Its many-sidedness and its alluring bypaths have tempted pupil and teacher alike. However enjoyable the *physical* side of it may be, it should not be forgotten that it is *geography*. Its greatest value arises from the fact that it introduces the student to his geographical environment and suggests to him how he may utilize it. Commerce, history, and even sociology have paid their tribute to this study. The intimate and necessary relation that exists between physical geography and history is the theme of more than one recent and valuable book. In this manual economic phases have been emphasized throughout.

In using our eyes we sometimes forget that we may use the eyes of others to our great pleasure and profit. In our attempts to study geography at first hand there is a temptation to neglect the library. While the author of this manual would be second to none in ascribing value to work done in the field and in the

laboratory, he believes that there is still a place for our old friend, the text-book. In order that the text-book may not be used slavishly, there have been called into requisition, in Part I of this manual, several of the latest texts and about fifty authoritative and readable treatises on different phases of physical geography. To prevent desultory reading and to avoid the disappointment of seeking without finding, all citations have been made definite, indicating to the pupil where he is to begin his reading and where to conclude it. Lest the pupil should read much and remember little, there have been introduced "special terms," which may serve as nuclei about which he may group the truths of the lesson.

In the preparation of Part II of this manual it has been borne in mind that all "out of doors" is the real laboratory for the study of geography; but, on the other hand, it has not been forgotten that the average traveler usually carries a "Baedeker." The ability to read a landscape correctly may be of primary importance; yet the ability to read a map correctly is invaluable. Therefore, in this manual much use has been made of the excellent and inexpensive maps of the Geological Survey, Coast and Geodetic Survey, Hydrographic Office, Weather Bureau, etc., at Washington. In those exercises requiring apparatus an attempt has been made to use only necessary and comparatively inexpensive pieces. While the author uses and recommends the use of many which are more complex and expensive, they are not referred to, partly because many schools are not now equipped with them, and partly because this is a pupil's guide and not a guide for the teacher. The wise teacher will use these pieces of apparatus, if available, in class exercises, and thus further whet the intellectual appetite of the pupil.

First of all the author is indebted for inspiration and helpful criticism to Principal Lewis B. Avery of the Union High School, Redlands, California. Many valuable suggestions have come from different members of the California Physical Geography Club, among whom should be mentioned Professor R. S.

Holway, University of California; Professor W. T. Skilling, State Normal School, San Diego; Miss Mabel B. Pierson, High School, Pasadena; Mr. C. S. Downes, High School, Berkeley; Professor James F. Chamberlain, State Normal School, Los Angeles; and Mr. George L. Leslie, City Schools, Los Angeles. Dr. Harold W. Fairbanks, of Berkeley, California, has kindly consented to the reproduction of twelve photographs selected from his excellent series of lantern slides.

The author wishes to acknowledge courtesies extended by Professors William Morris Davis, Ralph S. Tarr, Albert Perry Brigham, Charles R. Dryer, and Alexis E. Frye.

For any defects in this manual the author alone is responsible. Teachers will confer a favor if they will suggest improvements.

The author will be pleased to coöperate with teachers in the matter of furnishing lantern slides and other supplies.

C. T. WRIGHT

REDLANDS, CALIFORNIA
April, 1906

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Five outline maps of the United States, showing stations of the United States Weather Bureau, follow the text.

PHYSICAL GEOGRAPHY MANUAL

PART I

LIBRARY MANUAL

LIBRARY MANUAL

CHAPTER I

THE EARTH AMONG PLANETS

1. THE SOLAR SYSTEM

EXERCISE I. Magnitudes and Distances

Text-books.[1] Davis, 8–9. Davis Ele., 11–14. Gilbert and Brigham, 17–18. Redway, 9–12. Tarr, 3–6, 9–10.

Reference books.[2] Davis, *Elementary Meteorology:* 2–3[a],[3] The nebular hypothesis.

Fairbanks, *Rocks and Minerals:* 13–17, The beginning of the earth.

Newcomb, *Elements of Astronomy:* 32–34, The earth as a planet; 153–156, Venus; 156–159, Mars; 160–161, The asteroids; 162–167, Jupiter; 167–171, Saturn; 172–175, Uranus and Neptune; 176–186, Comets; 187–190, Meteors.

Shaler, *Outlines of the Earth's History:* 33[c]–39[a], The nebular hypothesis.

Young, *Lessons in Astronomy:* 204–208, Mercury; 209–214, Venus; 215–224, Mars; 225–230, The asteroids; 232–238, Jupiter; 239–245, Saturn; 245–250, Uranus and Neptune; 348–353, Cosmogony.

Special terms. Star, planet, satellite, asteroid, orbit, circle, ellipse, diameter, radius, solar system.

[1] See List of Text-Books in Appendix.
[2] See List of Reference Books in Appendix.
[3] Small letters appearing at the right of the figures indicate parts of pages, as follows: *a*, first half of page; *b*, second half of page; *c*, beginning near the bottom of the page.

2. THE FORM OF THE EARTH

EXERCISE II. The Oblateness of the Earth

Text-books. Davis, 10–14. Davis Ele., 1–6. Dryer, 9–12. Gilbert and Brigham, 1–2. Redway, 12–13. Tarr, 1–3.

Reference books. Newcomb, *Elements of Astronomy:* 17–19, Change of horizon as we travel; 80–89, Gravitation.

Young, *Lessons in Astronomy:* 78–81, Form, size, and measurement of the earth; 84^c–86^a, Effects of the earth's rotation on its form.

Special terms. Horizon, curved surface, uniformly curved surface, plane surface, sphere, spheroid, oblate spheroid, eclipse.

3. MOTIONS OF THE EARTH

EXERCISE III. The Direction of the Axis of Rotation

Text-books. Davis, 15–16. Davis Ele., 6–8. Dryer, 13–18. Gilbert and Brigham, 18–20. Redway, 13–14. Tarr, 6–9.

Reference books. Young, *Lessons in Astronomy:* 81–82, The rotation of the earth; 83–84, Invariability of the earth's rotation; 95, Changes in the earth's orbit.

Special terms. Apparent path of the sun, revolution, rotation, axis, cardinal points, up, down, zenith, nadir, antipodes, light, shadow, day, year, gravitation, centrifugal force.

4. INCLINATION OF THE EARTH'S AXIS

EXERCISE IV. Lengths of Day and Night

Text-books. Davis Ele., 46–52. Dryer, 19–22. Gilbert and Brigham, 20–25. Redway, 14. Tarr, 397–401.

Reference books. Newcomb, *Elements of Astronomy:* 23–28, Diurnal motions in different latitudes; 34–37, Motions and seasons.

Waldo, *Elementary Meteorology:* 22–24, Inclination of the earth's axis of rotation.

Young, *Lessons in Astronomy:* 95–97, Seasons; 98–99, Effects of inclination on temperature.

Special terms. Parallel, horizontal, perpendicular, vertical, pole star, plane of orbit, inclination, great circle, small circle, Tropic of Cancer, Tropic of Capricorn, Arctic Circle, Antarctic Circle, zone, width of zone, equinox, solstice, season.

5. THE SUN

EXERCISE V. North and South Line. VI. The Apparent Movements of the Sun

Reference books. Newcomb, *Elements of Astronomy:* 37–41, Apparent motion of the sun; 103–111, The sun.

Young, *Lessons in Astronomy:* 134–138, The sun's surface; 138–144, Sun spots; 156–161, Chromosphere, prominences, corona; 166–169, The heat of the sun.

6. THE MOON

EXERCISE VII. The Moon

Text-books. Redway, 11 (picture). Tarr, 9 (picture).

Reference books. Newcomb, *Elements of Astronomy:* 112–116, Distance, size, and aspects of the moon; 118–120, The moon's phases and rotation; 123–125, Eclipses of the moon; 126–131, Eclipses of the sun.

Shaler, *Aspects of the Earth:* 89ᶜ–92, The craters of the moon.

Young, *Lessons in Astronomy:* 113–114, Rotation of the moon; 114–116, Phases of the moon; 116–117, Earthshine on the moon; 117–118, Absence of air and water on the moon; 118–119, Light and heat of the moon; 120–125, Telescopic appearance and surface structure; 173–175, Lunar eclipses; 175–179, Eclipses of the sun.

Special terms. Phase, eclipse, reflection.

7. LATITUDE AND LONGITUDE

EXERCISE VIII. Latitude

Text-books. Davis, 388–393. Davis Ele., 8–11. Dryer, 23–25. Gilbert and Brigham, 2–4. Tarr, 402–405.

Reference books. Newcomb, *Elements of Astronomy:* 52–55, Longitude and time; 90–97, Measurements of the earth.

Special terms. Latitude, longitude, equator, prime meridian, Mercator's projection, conical projection, stereographic projection.

CHAPTER II

THE ATMOSPHERE

8. PHYSICAL PROPERTIES OF THE ATMOSPHERE

EXERCISE IX. Some Properties of the Atmosphere. X. Constituents of the Atmosphere. XI. Combustion and Oxidation

Text-books. Davis, 22–26. Davis Ele., 23–24, 27–29. Dryer, 273–279. Gilbert and Brigham, 223–226. Redway, 214–216. Tarr, 229–232.

Reference books. Davis, *Elementary Meteorology:* 3–4, Evolution and future of the atmosphere; 4–5, Composition of the atmosphere; 6–7, Oxygen and carbonic acid as related to plants and animals; 7^b–8, Economic aspects of the atmosphere; 13^b–14, Height of the atmosphere.

Fairbanks, *Rocks and Minerals:* 119–121, The work of oxygen; 122–125, Carbon, nitrogen, and hydrogen.

Shaler, *Aspects of the Earth:* 204^c–209, Gases in the atmosphere.

Shaler, *Outlines of the Earth's History:* 98–99, Composition and height of the atmosphere.

Waldo, *Elementary Meteorology:* 7–9, Constituents of the air.

Special terms. Weight, elasticity, transparency, pressure, density, oxygen, hydrogen, nitrogen, carbon dioxide.

9. HUMIDITY, EVAPORATION, CONDENSATION

EXERCISE XII. Evaporation and Condensation. XIII. Humidity

Text-books. Davis Ele., 60–62. Dryer, 280–282. Gilbert and Brigham, 226–227. Redway, 231–233. Tarr, 244–245.

Reference books. Harrington, *About the Weather:* 66–72, Humidity, or moisture; 227, The thermometer; 227c–231, The hygrometer.

Shaler, *Outlines of the Earth's History:* 156b–159a, Evaporation and condensation.

Waldo, *Elementary Meteorology:* 31–32, Thermometers; 118–121, Moisture of the atmosphere; 122–124, Humidity; 163–165, Evaporation.

Special terms. Water vapor, evaporation, humidity, relative humidity, absolute humidity, thermometer, wet bulb thermometer, hygrometer, saturation, condensation, precipitation.

10. DEW, FROST, FOG, CLOUDS

Text-books. Davis, 47, 403–404. Davis Ele., 61–64. Dryer, 282–286. Gilbert and Brigham, 227–230. Redway, 233–238. Tarr, 246–248.

Reference books. Harrington, *About the Weather:* 73–91, Dew, fog, cloud.

Shaler, *Outlines of the Earth's History:* 159–164, Dew, clouds.

Waldo, *Elementary Meteorology:* 129–135a, Clouds; 162, Dew, frost.

11. RAIN, SNOW, HAIL

Text-books. Davis, 45. Davis Ele., 38–39, 70. Dryer, 285, 327. Gilbert and Brigham, 230–231. Redway, 238, 242–243. Tarr, 249–250.

Reference books. Harrington, *About the Weather:* 92–98, Precipitation: rain and snow; 166–173, Storms of ice, sleet, ball snow, and hail.

Muir, *Mountains of California:* 41–47, Snow banners from mountain peaks; 123, Snow buries lakes in winter; 38, Snow and sludge bridge a stream in winter.

Shaler, *Outlines of the Earth's History:* 207b–208, Snow as a protective covering.

Waldo, *Elementary Meteorology:* 142–144, Rain; 159–161, Hail, snow.

12. LIGHT

EXERCISE XIV. Light

Text-books. Davis Ele., 27, 30, 63, 66. Gilbert and Brigham, 237. Redway, 277–281. Tarr, 232–233.

Reference books. Waldo, *Elementary Meteorology:* 166–169, Refraction, reflection, diffraction; 169, Mirage; 170–171[a], Colors of the sky; 171–174[a], Coronas and halos; 174[b]–175[a], Rainbows.

Special terms. Reflection, refraction, diffraction, spectrum, rainbow, halo, corona, mirage.

13. MAGNETISM AND ELECTRICITY

EXERCISE XV. Magnetism

Text-books. Davis, 398–399. Davis Ele., 17–19. Gilbert and Brigham, 274–278. Redway, 272–277. Tarr, 418–419.

Reference books. Shaler, *Outlines of the Earth's History:* 168, Aurora borealis.

Waldo, *Elementary Meteorology:* 175–179, Atmospheric electricity.

CHAPTER III

WINDS AND STORMS

14. INSOLATION, TEMPERATURE, ISOTHERMS

EXERCISE XVI. Isotherms

Text-books. Davis, 27–28. Davis Ele., 31–35. Dryer, 293–300. Gilbert and Brigham, 238–252.

Reference books. Davis, *Elementary Meteorology:* 18, Radiation from the sun.

Dodge, *Reader in Physical Geography:* 176–180, Temperature.

Harrington, *About the Weather:* 60–65, The temperature of the air; 187–193, The weather progress through the day and year.

Waldo, *Elementary Meteorology:* 25ᵇ–30, Insolation; 31–35, The thermometer; 36–39, Regular diurnal change of temperature; 40, Average daily temperature; 50–58, Isotherms.

15. ATMOSPHERIC PRESSURE

EXERCISE XVII. The Barometer. XVIII. Isobars

Text-books. Davis, 23–24. Davis Ele., 24–27. Dryer, 301–304. Gilbert and Brigham, 253–256.

Reference books. Harrington, *About the Weather:* 33–40, The pressure of the air and how it is measured; 41–47, Changes in the pressure of the air; 223–227[a], Barometers.

Waldo, *Elementary Meteorology:* 73–77, Atmospheric pressure and the barometer.

Special terms. Weight, pressure, barometer, isobar, low barometer, high barometer.

16. GENERAL MOVEMENTS OF THE ATMOSPHERE

EXERCISE XIX. Observations of the Weather. XX. Prevailing Winds

Text-books. Davis, 29–33. Davis Ele., 35–38, 53–58. Dryer, 287–292, 306–311. Gilbert and Brigham, 256–258, 266–268. Redway, 219–220. Tarr, 258–262.

Reference books. Dodge, *Reader in Physical Geography:* 185–188, Winds.

Harrington, *About the Weather:* 48–55, Winds — their kinds and distribution; 56–59, Measurement of the wind.

Shaler, *Aspects of the Earth:* 212–222, Winds.

Shaler, *First Book in Geology:* 56–61, Air; 98–101, General movements of the atmosphere.

Shaler, *Outlines of the Earth's History:* 101–106[a], Currents of the air.

Waldo, *Elementary Meteorology:* 101–104, Movements of the atmosphere; 187–191, General circulation of the atmosphere.

17. TRADE WINDS

Text-books. Davis, 30. Davis Ele., 39–44. Dryer, 306. Gilbert and Brigham, 259–260. Redway, 218. Tarr, 259–260.

Reference books. Harrington, *About the Weather:* 136–141, Effects of the earth's rotation upon the direction of the winds.

Shaler, *First Book in Geology:* 101–102, Trade winds.

Waldo, *Elementary Meteorology:* 195^{c}–198^{a}, Effect of the earth's rotation on air currents; 208–212, Trade winds, monsoons, doldrums.

18. CYCLONES AND ANTICYCLONES

EXERCISE XXI. Winds in a Cyclone. XXII. Areas of Precipitation. XXIII. Temperatures in Cyclones and Anticyclones

Text-books. Davis, 33–34. Davis Ele., 44–46, 74–81. Dryer, 304–306, 312–317. Gilbert and Brigham, 258–259. Redway, 248–250. Tarr, 262–267.

Reference books. Harrington, *About the Weather:* 99–109, General storms, cyclones, or lows; 110–116, Condensation in a cyclone; 128–135, The weather brought by the cyclone; 142–147, Anticyclones, or highs.

Shaler, *Aspects of the Earth:* 246–250, Cyclones; 250–255, Oceanic cyclones.

Shaler, *Outlines of the Earth's History:* 111–112, Cyclones.

Waldo, *Elementary Meteorology:* 216–227^{a}, Cyclones; 234^{c}–240, Anticyclones.

19. MOVEMENTS OF LOW BAROMETER IN THE UNITED STATES

EXERCISE XXIV. Movements of Low Barometer in the United States

Text-books. Davis, 49^{c}–51. Davis Ele., 79. Dryer, 317–318, 343. Gilbert and Brigham, 260. Redway, 260.

Reference books. Harrington, *About the Weather:* 117–127, Cyclones travel eastward.

20. HURRICANES. — TROPICAL CYCLONES

Text-books. Davis, 38–40. Davis Ele., 67–69. Dryer, 318–321. Gilbert and Brigham, 265–266. Redway, 250. Tarr, 269–271.

Reference books. Russell, *North America:* 209–212, Hurricanes.

Shaler, *Outlines of the Earth's History:* 106^b–110, Hurricanes.

Waldo, *Elementary Meteorology:* 229–230, Hurricanes and typhoons.

21. WEATHER FORECASTING

EXERCISE XXV. Weather Forecasting

Text-books. Davis, 52. Davis Ele., 81–82. Gilbert and Brigham, 268–269. Redway, 259–261.

Reference books. Harrington, *About the Weather:* xiii–xvi, Weather prediction is a science; 17–32, Economic aspects of the weather; 203–210, Weather predictions as a remedy against weather injuries; 211–222, The progress of knowledge of the weather.

Garriott, *Weather Folk-Lore and Local Weather Signs:* 5–28, Weather folk-lore; 29–47, Long-range weather forecasts; 49–153, Local weather signs; Charts I–XXI, Winds, clouds, barometric pressure.

Garriott, *Long-Range Weather Forecasts:* 3–4, Letter of transmittal and general statement; 7–10, Verification of long-range weather forecasts; 11–31, The planetary equinoxes; 37–68, Discussion of long-range weather forecasts.

Kenealy, *Weather Bureau Stations and their Duties:* 109–110, Origin and development of the meteorological service; 110^b–112^a, The daily weather forecasts; 115–120, The duties performed at the stations.

Waldo, *Elementary Meteorology:* 276–282^a, Weather maps; 282^b–292, Weather predictions.

22. TORNADOES

Text-books. Davis, 34. Davis Ele., 66–67. Dryer, 323–325. Gilbert and Brigham, 265. Redway, 255–259. Tarr, 267–269.

Reference books. Harrington, *About the Weather:* 156–165, Tornadoes or intense local whirls.

Russell, *North America:* 207–208, Tornadoes.

Shaler, *Aspects of the Earth:* 234–246, Tornadoes.

Shaler, *Outlines of the Earth's History:* 112^b–115, Tornadoes; 115^b–117^a, Waterspouts.

Shaler, *Story of Our Continent:* 130–132, Violent storms of North America.

Waldo, *Elementary Meteorology:* 241–249, Tornadoes; 259^b–261, Spouts.

23. THUNDERSTORMS

Text-books. Davis Ele., 65. Dryer, 325–326. Gilbert and Brigham, 264–265. Redway, 271.

Reference books. Harrington, *About the Weather:* 174–179, Thunderstorms and cloud-bursts.

Russell, *North America:* 206–207, Thunderstorms.

Shaler, *Outlines of the Earth's History:* 164^b–167^a, Thunderstorms.

Waldo, *Elementary Meteorology:* 249^c–259, Thunderstorms.

24. LOCAL WINDS

Text-books. Davis, 44. Davis Ele., 58–60. Gilbert and Brigham, 262–264. Redway, 222–224. Tarr, 256–257.

Reference books. Harrington, *About the Weather:* 148–155, "Betwixt and between weather"; 194–202, Local influences of the winds.

Shaler, *Aspects of the Earth:* 223–226, Land and sea breezes.

Shaler, *Outlines of the Earth's History:* 118^b–121^a, Land and sea breezes.

Waldo, *Elementary Meteorology:* 262–263, Periodic local winds; 263^b–268, Miscellaneous winds.

CHAPTER IV

CLIMATE

25. FACTORS OF CLIMATE

Text-books. Davis, 297–298. Dryer, 335–336. Gilbert and Brigham, 270. Redway, 287–290. Tarr, 275–279.

Reference books. Dodge, *Reader in Physical Geography:* 171–175, Weather and climate.

Moore, *Climate, Its Physical Basis and Controlling Factors:* 7, Weather and climate; 7–10, Basis of climate.

Waldo, *Elementary Meteorology:* 269–275, Weather conditions; 293–301, Climatic conditions.

26. RAINFALL

EXERCISE XXVI. Rainfall

Text-books. Davis, 45–47. Davis Ele., 70–74. Dryer, 327–334. Gilbert and Brigham, 231-236.

Reference books. Dodge, *Reader in Physical Geography:* 188–193, Moisture and rainfall.

Henry, *Average Annual Precipitation in the United States:* 207–213, Data for the period 1871 to 1901, with two maps.

Waldo, *Elementary Meteorology:* 148–156, Geographical distribution of annual rainfall.

27. ZONES OF CLIMATE

EXERCISE XXVII. Zones of Climate

Text-books. Davis, 52–53. Davis Ele., 82–85. Dryer, 336–348. Gilbert and Brigham, 246–250. Redway, 291–298. Tarr, 279–289.

Reference books. Dodge, *Reader in Physical Geography:* 180–184, Zones and heat belts; 194–197, Seasons and climate in different parts of the world.

Russell, *North America:* 186–191, The climate of Mexico and Central America; 191–194, The climate of the Atlantic and Gulf states; 194–201, The climate of central North America; 201–203, The climate of northern North America.

Waldo, *Elementary Meteorology:* 301[c]–306, Climatic zones; 307–312, Climates of the continents.

28. CHANGES OF CLIMATE

Text-books. Davis, 298. Davis Ele., 288–290.

Reference books. Moore, *Climate, Its Physical Basis and Controlling Factors:* 10–15, Variations in climate.

Waldo, *Elementary Meteorology:* 48, Long-period temperature oscillations.

29. CHANGES OF CLIMATE IN PAST GEOLOGICAL AGES

Text-books. Davis, 330–333. Gilbert and Brigham, 143–146. Redway, 290–291. Tarr, 147.

Reference books. Jordan, *Science Sketches:* 224–231, The story of a stone.

Shaler, *First Book in Geology:* 46–55, Coal and the coal age.

Shaler, *Outlines of the Earth's History:* 235, Warm weather at the poles; 244[b]–247[a], Causes of a glacial period.

Tarr, *Economic Geology of the United States:* 326–331, Conditions existing in Carboniferous times.

30. CLIMATIC REGIONS OF THE UNITED STATES

Text-books. Dryer, 341–346. Gilbert and Brigham, 270–272. Tarr, 291–293.

Reference books. Fairbanks, *Western United States:* 249–258, The climate of the Pacific coast.

Shaler, *Story of Our Continent:* 123–130, Climate of North America; 169–171, The frozen north; 171[c]–174[a], The arid regions; 174–176[a], North America compared with other continents; 176–178, Central United States; 178[c]–183, Atlantic and Pacific coasts compared.

Waldo, *Elementary Meteorology:* 313–321, Climatic regions of the United States; 322–335, Geographical distribution of temperature in the United States; 335–354, Geographical distribution of rainfall and humidity; 355–363, Geographical distribution of winds in the United States.

31. RELATION OF CLIMATE TO LIFE

Text-books. Davis, 1–7, 56. Davis Ele., 349–364. Dryer, 390. Gilbert and Brigham, 189–193, 359–366.

Reference books. Moore, *Climate, Its Physical Basis and Controlling Factors:* 15–19, Economic aspects of climate.

Shaler, *Story of Our Continent:* 2–6, Relations of climate to life.

CHAPTER V

THE STRUCTURE OF THE EARTH

32. THE EARTH AS A WHOLE

Text-books. Davis Ele., 15–17. Dryer, 26–29. Gilbert and Brigham, 4–5. Redway, 20–22. Tarr, 13–19.

Reference books. Davis, *Elementary Meteorology:* 9–10[a], The geosphere, hydrosphere, and atmosphere.

Dodge, *Reader in Physical Geography:* 4–9, Our relation to the world as a whole.

Heilprin, *The Earth and Its Story:* 111–116, The earth in its interior.

Winchell, *Walks and Talks in the Geological Field:* 117–124, Imprisoned heat.

Special terms. Sphere, centrosphere, lithosphere, hydrosphere, atmosphere, molten mass, density, crust of the earth.

33. THE LAND

EXERCISE XXVIII. Elevations and Depressions of the Earth's Surface drawn to Scale

Text-books. Davis, 93–95. Davis Ele., 129–139. Dryer, 38–46. Tarr, 19[b]–28.

Reference books. Dodge, *Reader in Physical Geography:* 10–17, The larger features of the continents.

Heilprin, *The Earth and Its Story:* 94–99, The ocean trough; 185–188, Physiognomy of continents.

Shaler, *Outlines of the Earth's History:* 82[b]–84, Height, area, and distribution of the land.

Shaler, *Story of Our Continent:* 76–78[a], Outlines of North America; 148–150, The continental shelf of North America.

Special terms. Coastal shelf, hemisphere, great circle, pole of great circle, land hemisphere.

34. SLOW MOVEMENTS OF THE EARTH'S CRUST

Text-books. Davis, 95–97. Davis Ele., 132. Dryer, 46–48. Gilbert and Brigham, 10–12. Redway, 23–25.

Reference books. Brigham, *Geographic Influences in American History:* 114[b]–115[a], Tilting of the basin of the Great Lakes.

Russell, *Rivers of North America:* 179[b]–180[a], Terraces of the Colorado river due to elevation of land.

Shaler, *Aspects of the Earth:* 1–9, Upgrowth of the continents.

Shaler, *First Book in Geology:* 141–145, Slow vertical movements.

Shaler, *Sea and Land:* 169–173, Slow rising and falling of the land.

Special terms. Sedimentary rock, stratum, strata, fossil, lateral pressure.

35. CAUSES OF MOUNTAINS

Text-books. Davis Ele., 177–178. Dryer, 190–193. Redway, 65–69. Tarr, 93–99.

Reference books. Crosby, *Common Minerals and Rocks:* 166–177, Folds; 180–188, Faults.

Dodge, *Reader in Physical Geography:* 144–149, Mountains.

Fairbanks, *Western United States:* 50–59, Earthquakes and mountain building.

Heilprin, *The Earth and Its Story:* 44–49, What a mountain teaches; 188–194, Physiognomy of mountains; 202–203, Physiognomy of rock masses.

Shaler, *First Book in Geology:* 107–112, Folds.

Shaler, *Outlines of the Earth's History:* 85–91, Causes and characteristics of mountains.

Tarr, *Elementary Geology:* 324–328, Wrinkling of the earth's crust, contraction theory.

Winchell, *Walks and Talks in the Geological Field:* 139–145, How the mountain framework is reared.

Special terms. Lateral pressure, weight of sediment, fold, anticline, syncline, fault, degradation, erosion.

36. KINDS OF MOUNTAINS

Text-books. Davis, 161–171. Davis Ele., 178–185. Dryer, 178–179, 181–183. Gilbert and Brigham, 174–181. Tarr, 100–101.

Reference books. Brigham, *Geographic Influences in American History:* 257–259, 268–272, The Rocky mountains; 287–289, The mountains of the Pacific coast.

Dodge, *Reader in Physical Geography:* 149–150, Kinds of mountains.

Muir, *Mountains of California:* Chapter I, General description of the Sierra Nevada.

Russell, *North America:* 74–82, The Appalachian mountains; 122–131, The Rocky mountains; 147–158, The Sierra Nevada and Cascade mountains.

Special terms. Folded mountains, mountains by faulting, block mountains.

37. LIFE HISTORY OF MOUNTAINS

Text-books. Davis, 172–175, 187–197. Davis Ele., 185–188, 204–212. Dryer, 183–190. Gilbert and Brigham, 182–185. Redway, 69–70. Tarr, 101–103.

Reference books. Dodge, *Reader in Physical Geography:* 150–153, Aging of mountains.

Special terms. Dissection, relict, subdued, monadnock.

38. ECONOMIC ASPECTS OF MOUNTAINS

Text-books. Davis, 175–178, 184–186. Davis Ele., 188–191, 204, 357–359. Gilbert and Brigham, 188–195. Redway, 72–75. Tarr, 105–109.

Special terms. Tree line, snow line, barrier, pass, sentinel.

39. COASTAL PLAINS

Text-books. Davis, 117–136. Davis Ele., 141–158. Gilbert and Brigham, 151–155. Tarr, 72–76.

Reference books. Brigham, *Geographic Influences in American History:* 70–75, The Atlantic coastal plain; 173–180, The Atlantic coastal plain from Virginia to Florida.

Russell, *North America:* 62–73, Coastal plains of North America; 94–99, The Gulf plains.

40. PLAINS AND PLATEAUS

Text-books. Davis, 139–150. Davis Ele., 158–170. Gilbert and Brigham, 155–167. Redway, 56–65. Tarr, 76–85.

Reference books. Brigham, *Geographic Influences in American History:* 148–155, Description of the prairies; 230–239, The Great Plains.

Dodge, *Reader in Physical Geography:* 137–143, Plains and plateaus.

Heilprin, *The Earth and Its Story:* 194–196, Physiognomy of plateaus.

Russell, *North America:* 250–253, Prairies, treeless plains, and plateaus.

Shaler, *Story of Our Continent:* 121–123, Prairies of North America.

Special terms. Plain, plateau, base level of erosion, coastal plain, lacustrine plain, alluvial plain.

41. REPRESENTATION OF RELIEF

EXERCISE XXIX. Contour Lines. XXX. Contour Maps

Text-books. Davis, 393–397. Dryer, 48–53. Gilbert and Brigham, 14–16. Tarr, 428–430.

Reference books. Brigham, *Geographic Influences in American History:* 332–338, The work of the U.S. Geological Survey.

Topographic Atlas of the U.S. Geological Survey, Folios 1 and 2: 1, Introduction and Topographic map.

Topographic maps of U.S. Geological Survey: Printed matter on back of map.

Special terms. Hachures, contour, profile.

CHAPTER VI

DISINTEGRATION AND EROSION

42. DISINTEGRATION OF ROCK

EXERCISE XXXI. The Weathering of Rocks

Text-books. Davis, 99–105, 265–268. Davis Ele., 134–138. Dryer, 58–60. Tarr, 38–42.

Reference books. Dodge, *Reader in Physical Geography:* 69–73, Weathering; 120–121, Effects of cold and frost on rocks.

Jordan, *Science Sketches:* 232–255, An ascent of the Matterhorn.

Russell, *Rivers of North America:* 2–3, Mechanical disintegration; 236–240, Vegetation hastens weathering.

Shaler, *First Book in Geology:* 3^b–4, Frost as a weathering agent; 21^b–23, Oxygen, acids, worms, roots as weathering agents.

Special terms. Disintegrate, oxidize.

43. RESIDUAL SOIL, CREEP, TALUS

Text-books. Davis, 268–275. Davis Ele., 163–164, 196–197. Dryer, 168. Tarr, 42–46.

Reference books. Russell, *Rivers of North America:* 13-16[a], How rivers obtain their loads.

Shaler, *Outlines of the Earth's History:* 322[a], Residual soil.

Special terms. Mantle rock, residual soil, creep, talus.

44. THE LOAD OF A STREAM

EXERCISE XXXII. The Assorting Power of Water

Text-books. Dryer, 61–65. Gilbert and Brigham, 31–35. Redway, 107–109. Tarr, 50–52.

Reference books. Crosby, *Common Minerals and Rocks:* 19–23, Deposition.

Russell, *Rivers of North America:* 20–22, Transportation of material; 240–244, Driftwood.

Shaler, *Aspects of the Earth:* 146–151, Velocity as related to carrying power.

Shaler, *First Book in Geology:* 20–21, Assorting power of running water.

Tarr, *Elementary Geology:* 174–175, Transportation of sediment.

Winchell, *Walks and Talks in the Geological Field:* 51–52, Transporting and assorting power of running water; 57–60, Source and journey of sediments.

Special terms. Suspension, velocity, sediment, silt.

45. CORRASION AND ABRASION

EXERCISE XXXIII. Examination of Rock Waste

Text-books. Dryer, 65–67. Tarr, 52–53.

Reference books. Crosby, *Common Minerals and Rocks:* 14–19, Mechanical erosion.

Dodge, *Reader in Physical Geography:* 81–88, Erosive work of running water.

Russell, *Rivers of North America:* 28–32, Corrasion.

Shaler, *First Book in Geology:* 1–4, Abrasion of river pebbles; 12–19, Sand.

Special terms. Corrasion, abrasion, erosion.

46. MESAS, BUTTES, BAD LANDS

Text-books. Davis, 150–152, 219[b]–221. Davis Ele., 171–175. Dryer, 214–216. Gilbert and Brigham, 89–93. Tarr, 82–83.

Reference books. Crosby, *Common Minerals and Rocks:* 198–200, Table mountains.

CHAPTER VII

RIVERS

47. CANYONS

Text-books. Davis Ele., 164–167. Dryer, 84–91. Gilbert and Brigham, 28–33.

Reference books. Fairbanks, *Western United States:* 10–18, Grand Canyon of the Colorado; 31–40, Canyons of the Sierra Nevada mountains.

Heilprin, *The Earth and Its Story:* 53–55, Canyons.

Shaler, *Story of Our Continent:* 138–140, Canyons.

Tarr, *Elementary Geology:* 170–173, The Colorado canyon.

Winchell, *Walks and Talks in the Geological Field:* 61–62, River gorges.

Special terms. Canyon, gorge, ravine, gully, gulch, terrace.

48. WATERFALLS AND RAPIDS

EXERCISE XXXIV. A Waterfall

Text-books. Davis Ele., 251–256. Dryer, 95–101. Gilbert and Brigham, 38–42. Redway, 119–121. Tarr, 53–54.

Reference books. Dodge, *Reader in Physical Geography:* 96–98, Rapids and waterfalls.

Russell, *Rivers of North America:* 60–63, Migration of waterfalls; 33–34[a], Potholes.

Shaler, *Aspects of the Earth:* 159–165, Waterfalls.

Shaler, *Outlines of the Earth's History:* 191–193[a], Waterfalls.

Shaler, *Story of Our Continent:* 136–138, Waterfalls.

Special terms. Rapids, cascades, escarpment, fall rock, dip, migration, pothole.

49. VALLEYS

Text-books. Davis, 239-246, 278-286. Davis Ele., 196-201, 256-258. Dryer, 60. Gilbert and Brigham, 43-45, 57-59. Tarr, 54-59.

Reference books. Heilprin, *The Earth and Its Story:* 196-199, Physiognomy of valleys.

Russell, *Rivers of North America:* 52-54[a], Gradient of river bed; 145-150, Longitudinal profile of valleys; 150-151, Cross profile of valleys.

50. FLOOD PLAINS

EXERCISE XXXV. River Flood Plains

Text-books. Davis, 286-288. Davis Ele., 258-261. Dryer, 73-79. Gilbert and Brigham, 45-49. Redway, 113-115. Tarr, 61-63.

Reference books. Brigham, *Geographic Influences in American History:* 180-186, The flood plain of the lower Mississippi.

Dodge, *Reader in Physical Geography:* 88-92, Alluvial plains.

Russell, *Rivers of North America:* 110-116, Flood plains; 116-123, Natural levees.

Shaler, *Outlines of the Earth's History:* 186-187[a], River flood plains.

Tarr, *Elementary Geology:* 178-179, Flood plains.

Special terms. Flood, overflow, levee, crevasse, back swamp, bayou, flood plain.

51. TERRACES

Text-books. Davis, 280. Davis Ele., 199-200. Dryer, 160-161. Gilbert and Brigham, 52-54. Redway, 115. Tarr, 63-64.

Reference books. Heilprin, *The Earth and Its Story:* 59-60, River terraces.

Russell, *Rivers of North America:* 179[b]-183, Terraces of the Colorado river and the Columbia.

Tarr, *Elementary Geology:* 180, Terraces.

Winchell, *Walks and Talks in the Geological Field:* 50-51, River terraces.

52. MEANDERS, OXBOWS, LAGOONS

EXERCISE XXXVI. Meanders

Text-books. Davis, 241–246. Davis Ele., 261–265. Dryer, 75–76, 158. Gilbert and Brigham, 49–52. Redway, 109–110. Tarr, 62–63.

Reference books. Russell, *Rivers of North America*: 36–38, Meandering streams.

Shaler, *Aspects of the Earth*: 152–155[a], Oxbows, or moats.

Shaler, *Outlines of the Earth's History*: 180[b]–183, Meanders, oxbows.

Special terms. Graded, sediment, deposit, velocity, meander, oxbow, lagoon.

53. DELTAS, FANS, CONES

EXERCISE XXXVII. Alluvial Cones

Text-books. Davis, 275–278, 288–296. Davis Ele., 196–199, 265–269. Dryer, 78. Gilbert and Brigham, 42–43, 54–57. Redway, 115–119. Tarr, 64–67.

Reference books. Dodge, *Reader in Physical Geography*: 92–96, Alluvial fans and deltas.

Russell, *Rivers of North America*: 101–109, Alluvial cones and fans; 123–125, Deltas; 125–127[a], Deltas of high-grade streams; 130–132, Deltas of low-grade streams.

Shaler, *Sea and Land*: 162[c]–166, Deltas.

Tarr, *Elementary Geology*: 176–177, Alluvial fans; 180–186, Deltas.

Winchell, *Walks and Talks in the Geological Field*: 54–56, River sediments.

Special terms. Delta, fan, cone, distributary, estuary, bayou.

54. LIFE HISTORY OF A RIVER

EXERCISE XXXVIII. A Region in Youth. XXXIX. A Region in Maturity. XL. A Region in Old Age. XLI. The Life History of a River

Text-books. Davis, 231–233, 237–239, 251–252. Davis Ele., 246–250, 254–255, 269–270, 270–273. Dryer, 152–156. Gilbert and Brigham, 57–60. Redway, 110–112.

Reference books. Dodge, *Reader in Physical Geography:* 98–99, Results of the work of running water.

Fairbanks, *Western United States:* 124–132, The Skagit river.

Heilprin, *The Earth and Its Story:* 53, Base level of erosion.

Russell, *Rivers of North America:* 46^{c}–49^{b}, Base level of erosion; 300–310, Life history of a river; 311–320, Completion of geographical cycle.

55. RIVER SYSTEMS

EXERCISE XLII. The Drainage Areas of the United States

Text-books. Davis, 230. Davis Ele., 241–243. Dryer, 61, 79–80. Gilbert and Brigham, 36, 59.

Reference books. Winchell, *Walks and Talks in the Geological Field:* 60–61, Drainage areas.

Special terms. River, tributary, river system, basin, divide, portage.

56. MIGRATION OF DIVIDES

EXERCISE XLIII. The Migration of Divides

Text-books. Davis, 246–250. Dryer, 157–158. Gilbert and Brigham, 65–66. Redway, 121.

Reference books. Russell, *Rivers of North America:* 199–205, Stream conquest; 247–253, Migration of divides.

57. CONSEQUENT, ANTECEDENT, ENGRAFTED, DROWNED RIVERS

Text-books. Davis, 258–260. Dryer, 162. Tarr, 103–104.

Reference books. Heilprin, *The Earth and Its Story:* 55–59, Valleys, water gaps.

Shaler, *Sea and Land:* 167–168, 173–174, Drowned rivers.

58. TYPICAL RIVERS

Text-books. Davis, 260–261. Dryer, 68–80, 81–91, 92–101. Gilbert and Brigham, 66–73. Tarr, 320–321, 322–325, 325–329, 329–334.

Reference books. Fairbanks, *Western United States:* 1–9, The work of the Colorado river.

Russell, *Rivers of North America:* 43–45, Typical rivers — St. Lawrence, Missouri, Colorado; 271–275, The Colorado; 275–278[a], Rivers of the Sierra Nevada; 296–298, The Niagara.

59. ECONOMIC IMPORTANCE OF RIVERS

Text-books. Dryer, 163–167. Redway, 126. Tarr, 105–109.

Reference books. Shaler, *Aspects of the Earth:* 185–193, How removal of forests affects rivers; 193–196, Rivers and irrigation.

CHAPTER VIII

LAND FORMS DUE TO OTHER AGENCIES

60. TYPICAL VOLCANOES

Text-books. Davis, 201–207, 209–219. Davis Ele., 216–224, 227–233. Dryer, 194–203. Gilbert and Brigham, 196–208. Tarr, 112–122.

Reference books. Fairbanks, *Rocks and Minerals:* 13–17, The beginning of the earth (Kilauea).

Heilprin, *The Earth and Its Story:* 117–120, Vesuvius.

Russell, *Volcanoes of North America:* 2–7, Stromboli; 7–22, Vesuvius; 22–29, Krakatoa; 29–36, Hawaiian volcanoes.

Shaler, *Aspects of the Earth:* 46–56, Pliny's account of the great eruption of Vesuvius; 62–64, Looking into the crater of Vesuvius; 74–76, The eruption of Krakatoa.

Shaler, *Outlines of the Earth's History:* 263–266[a], A near view of the crater of Vesuvius in eruption; 276[c]–282, Eruptions of Vesuvius from 63 A.D. to 1872; 289[b]–297[a], Ætna; 298[b]–300, Krakatoa.

Winchell, *Walks and Talks in the Geological Field:* 103–111, Among the volcanoes.

61. VOLCANIC PHENOMENA

EXERCISE XLIV. Specific Gravity. XLV. Volcanic Rocks. XLVI. Volcanic Peaks, Plateaus, and Necks. XLVII. A Crater

Text-books. Davis, 199–201, 208–209. Davis Ele., 215–216, 226–227. Dryer, 203–209. Gilbert and Brigham, 208–219. Redway, 80–90. Tarr, 122–130.

Reference books. Crosby, *Common Minerals and Rocks:* 109–110, Eruptive rocks; 114[b]–122, Volcanic rocks; 148–156, Dikes, intrusive beds, volcanic necks, etc.

Dodge, *Reader in Physical Geography:* 154–162, Volcanoes.

Fairbanks, *Rocks and Minerals:* 59–62, The story of volcanic rocks; 63–66, Different kinds of volcanic rocks.

Fairbanks, *Western United States:* 19–30, How the Columbia plateau was made; 60–69, Latest volcanic eruptions in the United States; 70–74, Mud volcanoes of the Colorado desert.

Heilprin, *The Earth and Its Story:* 120–127, Volcanic phenomena; 127–132, Causes and distribution of volcanoes.

Muir, *Mountains of California:* 11, Most recent eruption in the Sierras.

Russell, *Lakes of North America:* 20–21, Crater lake.

Russell, *Volcanoes of North America:* 193–198, Mt. Taylor; 225–228, Mt. Shasta, California; 235–236, Crater lake, Oregon; 241–245, Mt. Rainier; 250–257, Columbia lava flow; 96–103, Dikes, sheets, plugs; 83–90, Structure of volcanic mountains; 208–217, Mono lake, California; 228–233, Cinder cone and lava field near Lassen's peak, California.

Shaler, *Aspects of the Earth:* 77–89, Distribution and cause of volcanoes; 89[c]–92, The craters of the moon; 92–97, Economic aspects of volcanoes.

Shaler, *First Book in Geology:* 88–97, Volcanoes.

Shaler, *Outlines of the Earth's History:* 303–304, Lava sheets; 305–309, Dikes; 266–271, Causes of volcanoes; 288–289[a], 309[b]–312, Economic aspects of volcanoes.

Tarr, *Elementary Geology:* 329–352, Volcanoes.

Winchell, *Walks and Talks in the Geological Field:* 111–117, Frozen seas of lava.

Special terms. Crater, cinder cone, lava, lava flow, scoria, pumice, volcanic neck, dike.

62. EARTHQUAKES

Text-books. Davis, 183–184. Davis Ele., 201–204. Dryer, 190–191. Gilbert and Brigham, 220–222. Redway, 95–100. Tarr, 130–132.

Reference books. Dodge, *Reader in Physical Geography:* 163–164, Earthquakes.

Heilprin, *The Earth and Its Story:* 132–137, Earthquakes.

Shaler, *Aspects of the Earth:* 13–17, Causes of earthquakes; 27–39, Earthquakes in the United States; 39–42, Construction of buildings to withstand earthquakes; 42–45, Earthquake waves at sea.

Shaler, *First Book in Geology:* 130–140, Earthquakes.

Shaler, *Story of Our Continent:* 258–262, Earthquakes.

Shaler, *Outlines of the Earth's History:* 367–371, Transmission of earthquake shocks; 371[b]–376, Effects of earthquakes.

Tarr, *Elementary Geology:* 353–361, Earthquakes.

Winchell, *Walks and Talks in the Geological Field:* 125–132, Phenomena and causes of earthquakes.

Special terms. Stress, fault, focus, concentric circles, concentric spheres.

63. LANDSLIDES

Text-books. Davis Ele., 193–195. Dryer, 168. Gilbert and Brigham, 105–108. Tarr, 97.

Reference books. Muir, *Mountains of California:* 104–109, Landslide filling a lake; 40, Avalanches of snow.

Shaler, *Outlines of the Earth's History:* 174–177, Landslides.

64. ALPINE GLACIERS

EXERCISE XLVIII. Glaciers

Text-books. Davis, 326–330. Davis Ele., 292–294. Dryer, 108–117. Gilbert and Brigham, 119–128. Redway, 153–156. Tarr, 137–142.

Reference books. Dodge, *Reader in Physical Geography:* 121–127, Glaciers; 127–132, Deposits made by glaciers.

Fairbanks, *Western United States:* 41–49, An Oregon glacier.

Heilprin, *The Earth and Its Story:* 65–74, Snow and glaciers; 75–82, The work of glaciers.

Muir, *Mountains of California:* 15, A receding glacier; 16–18, Magnitude of work done by glaciers; 26–27, Polishing of rock surface by a glacier; 31–33, A trip over a glacier; 81–82, Amount of work done by glaciers; 103–104, Beginning of vegetation after glaciation; 69, An imaginary view of the Sierras in the Glacial epoch.

Russell, *Glaciers of North America:* 2–16, Leading characteristics of glaciers; 18–21, Glacial abrasion; 22–28, Glacial deposits; 28–30, Glacial sediments; 30–31, Changes in topography produced by glaciers; 55–62, The glaciers of Mt. Shasta; 62–67, The glaciers of Mt. Rainier; 67–69, The glaciers of Mt. Hood; 190–205, The life history of a glacier.

Shaler, *First Book in Geology:* 8–12, Glacial pebbles.

Shaler, *Outlines of the Earth's History:* 211^{b}–212, An avalanche in the Alps; 213–215^{a}, The névé; 215^{b}–216^{a}, The glacier proper; 216^{b}–218^{a}, Débris carried by a glacier; 218–221, Crevasse, moulin, esker; 221^{b}–223^{a}, "Milky" water in glacial streams.

Tarr, *Elementary Geology:* 195–219, Glaciers.

Winchell, *Walks and Talks in the Geological Field:* 24–32, Among the glaciers.

Special terms. Névé, crevasse, moraine, ground moraine, lateral moraine, terminal moraine, striæ, cirque, alpine glacier, mountain glacier, valley glacier.

65. PIEDMONT AND CONTINENTAL GLACIERS

Text-books. Davis, 324–326, 330–333. Davis Ele., 290–292, 294–295. Dryer, 117–121. Gilbert and Brigham, 128–132. Redway, 156–158. Tarr, 143–147.

Reference books. Russell, *Glaciers of North America:* 80–91, Muir glacier; 109–127, Malaspina glacier; 131–145, Glaciers in the Greenland region.

Shaler, *Outlines of the Earth's History:* 225^{b}–228^{a}, Continental glaciers.

Muir, *Mountains of California:* Chapter II, The glaciers.

Special terms. Piedmont glacier, continental glacier, medial moraine.

66. THE WORK OF ANCIENT GLACIERS

EXERCISE XLIX. Topographic Forms due to Glaciation

Text-books. Davis, 333–346. Davis Ele., 295–302. Dryer, 122–134. Gilbert and Brigham, 132–144, 144–150. Redway, 158–162. Tarr, 148–156.

Reference books. Brigham, *Geographic Influences in American History:* 41^{b}–45, Changes wrought by ancient glaciers in New England; 115–126, The Great Lakes during and since Glacial times.

Dodge, *Reader in Physical Geography:* 132–135, The work of the great ice sheet.

Heilprin, *The Earth and Its Story:* 82–86, The great Ice Age.

Shaler, *Story of Our Continent:* 64^{c}–69^{a}, The advance and extent of the ancient ice sheet; 69–72^{a}, The retreat and the effects of the great glacier; 72–75, Organic life during the glacial period.

Winchell, *Walks and Talks in the Geological Field:* 11–17, Lost rocks, bowlders; 17–24, Arrangement of the drift; 45–50, The floods of the Great Lakes.

Special terms. Kettle hole, drift, loess, till, kame, drumlin, erratic.

67. DESERTS

Text-books. Davis Ele., 280–283. Redway, 296–298. Tarr, 86–89.

Reference books. Brigham, *Geographic Influences in American History:* 245–251, The Great Basin and the arid regions of the southwest; 251–254, The civilization of desert countries.

Fairbanks, *Western United States:* 187–197, The life of the desert.

Heilprin, *The Earth and Its Story:* 17–18, Desert sands and deserts.

Shaler, *Outlines of the Earth's History:* 340^{b}–341, Arid regions.

68. SAND DUNES

Text-books. Davis, 314–319. Davis Ele., 286–289. Gilbert and Brigham, 109–118. Redway, 224–227. Tarr, 87–88.

Reference books. Dodge, *Reader in Physical Geography:* 76–80, The wind.

Roth, *First Book of Forestry:* 198–202, Sand dunes checked by forests.

Shaler, *First Book in Geology:* 17–18, Dunes.

Shaler, *Sea and Land:* 49–52, Dunes of sea sand.

Tarr, *Elementary Geology:* 129–138, Wind erosion.

Westgate, *Reclamation of Cape Cod Sand Dunes:* 9–17, Causes and development of sand dunes; 18–20, Devastation of the established dune areas; 21–34, Artificial reclamation of Cape Cod sands; 34–35, The Province lands; 38 ff., Plates and description.

Special terms. Sand blast, dune, migration.

69. CORAL REEFS

Text-books. Davis, 374–383. Davis Ele., 324–330. Dryer, 174–177. Gilbert and Brigham, 283–286. Tarr, 217–219.

Reference books. Heilprin, *The Earth and Its Story:* 138–149, Corals and coral islands.

Jordan, *Science Sketches:* 224–228, The life of the coral polyp.

Shaler, *Sea and Land:* 86^{b}–87, 203–207, Coral reefs; 207^{b}–209, Atolls.

Shaler, *Story of Our Continent:* 150–152, Coral reefs.

CHAPTER IX

IMPERFECT DRAINAGE

70. LAKES, SWAMPS, MARSHES

EXERCISE L. Lakes

Text-books. Davis, 232–234. Davis Ele., 248–250. Dryer, 150–151. Gilbert and Brigham, 60–62. Redway, 165–169, 177–183. Tarr, 160–170.

Reference books. Brigham, *Geographic Influences in American History:* 115, Depth of the Great Lakes.

Dodge, *Reader in Physical Geography:* 113–118, Lakes.

Fairbanks, *Western United States:* 133–140, The story of Lake Chelan.

Heilprin, *The Earth and Its Story:* 60–62, Lake basins and meadow lands.

Muir, *Mountains of California:* 104–108, Death of a lake.

Russell, *Lakes of North America:* 90–95, Life history of lakes.

Shaler, *First Book in Geology:* 125–129, Lakes.

Shaler, *Outlines of the Earth's History:* 198–206, Lakes; 331–335, Bogs; 335[c]–340, Marine marshes.

Tarr, *Elementary Geology:* 188–194, Destruction of lakes.

Winchell, *Walks and Talks in the Geological Field:* 52[b]–54, The filling of ponds.

71. INTERIOR BASINS AND SALT LAKES

Text-books. Davis, 304–314. Davis Ele., 283–285. Dryer, 135–149. Gilbert and Brigham, 158–160. Redway, 169–170. Tarr, 163–164.

Reference books. Fairbanks, *Western United States:* 95–105, The Great Basin and its peculiar lakes; 115–123, The story of Great Salt Lake.

Russell, *North America:* 136–146, The Great Basin.

Shaler, *Story of Our Continent:* 212–213, Mineral substances in sea water.

72. EXTINCT LAKES

EXERCISE LI. Extinct Lakes

Text-books. Davis Ele., 288–290. Gilbert and Brigham, 155–160. Redway, 170–177. Tarr, 164–165.

Reference books. Fairbanks, *Western United States:* 168–175, Death valley.

Heilprin, *The Earth and Its Story:* 62–64, Ancient lake basins.

Shaler, *Story of Our Continent:* 146–148, Dead seas.

CHAPTER X

UNDERGROUND WATERS

73. PERCOLATING WATERS

Text-books. Davis, 224–225. Davis Ele., 234–235. Gilbert and Brigham, 104–105. Redway, 132–134, 139–142. Tarr, 39–40.

Reference books. Tarr, *Elementary Geology:* 150, Underground waters.

Special terms. Run-off, percolate, vegetable mold, impervious strata.

74. CAVERNS

EXERCISE LII. Solids in Solution

Text-books. Davis, 225–226. Davis Ele., 235–236. Dryer, 104–105. Gilbert and Brigham, 98–100. Tarr, 59–60.

Reference books. Muir, *Mountains of California:* 329–330, Caves of the mountains of California; 333–337, A visit to a cave.

Shaler, *Aspects of the Earth:* 98–115, Caverns and natural bridges.

Shaler, *First Book in Geology:* 74–87, The course of water underground.

Shaler, *Outlines of the Earth's History:* 250–251, Dissolving power of water having carbon dioxide in it; 253–255, Caverns; 255[b]–256, Stalactites; 256[b]–258, Natural bridges.

Shaler, *Story of Our Continent:* 140–145, Caverns.

Tarr, *Elementary Geology:* 140–143, Caves.

Special terms. Solid, solvent, solution, saturated solution, sediment, evaporation, stalactite, stalagmite.

75. SPRINGS

Text-books. Davis, 226–229. Davis Ele., 236–239. Dryer, 105–106. Gilbert and Brigham, 100–103. Redway, 135–136.

Reference books. Dodge, *Reader in Physical Geography:* 206–212, Springs and wells.

Heilprin, *The Earth and Its Story:* 87, Mineral waters; 91–93, Hot springs and geysers.

Shaler, *Aspects of the Earth:* 123–130, Caverns formed by hot springs.

Shaler, *Story of Our Continent:* 253–258, Underground water.

Tarr, *Economic Geology of the United States:* 418–420, Mineral waters.

Tarr, *Elementary Geology:* 145–147, Springs.

Winchell, *Walks and Talks in the Geological Field:* 32–38, The hillside spring and its work.

76. ARTESIAN WELLS

Text-books. Davis, 126–127. Davis Ele., 238. Dryer, 102–103. Gilbert and Brigham, 103–104. Redway, 135. Tarr, 72[b]–73.

Reference books. Shaler, *Outlines of the Earth's History:* 258[b]–259, Artesian wells.

Tarr, *Economic Geology of the United States:* 412–418, Artesian wells.

Tarr, *Elementary Geology:* 147–149, Artesian wells.

77. GEYSERS

Text-books. Davis, 229–230. Davis Ele., 239–241. Dryer, 106. Gilbert and Brigham, 103. Redway, 136–138. Tarr, 132–133.

Reference books. Dodge, *Reader in Physical Geography:* 164, Geysers and hot springs.

Jordan, *Science Sketches:* 256–263, The formation of geysers.

Tarr, *Elementary Geology:* 362–365, Geysers.

Winchell, *Walks and Talks in the Geological Field:* 93–102, A walk in the Yellowstone park.

78. VEINS

EXERCISE LIII. Veins

Reference books. Crosby, *Common Minerals and Rocks:* 123–126, Vein rocks; 156[b]–165, The structure of veins.

Fairbanks, *Rocks and Minerals:* 67–70, The story of a piece of quartz; 71–75, Some varieties of quartz.

Shaler, *First Book in Geology:* 66–73, Veins.

Shaler, *Outlines of the Earth's History:* 259[b]–261, Mineral veins.

Shaler, *Story of Our Continent:* 213–214, Method of formation of veins.

CHAPTER XI

THE OCEAN

79. SOUNDINGS

Text-books. Davis, 61–62. Davis Ele., 98–99. Gilbert and Brigham, 298–299. Tarr, 173–174.

Reference books. Shaler, *Sea and Land:* 75–80, Soundings.

Special terms. Fathom, dredge, self-registering thermometer.

80. THE SEA BOTTOM

Text-books. Davis, 67–71. Davis Ele., 105–109. Dryer, 243–249. Gilbert and Brigham, 279–282. Tarr, 175–178.

Reference books. Brigham, *Geographic Influences in American History:* 350[c]–354, The work of the U.S. Coast Survey and the Hydrographic Office.

Shaler, *Sea and Land:* 80[b]–86[a], The shape of the sea floor; 105, Ooze; 108–114, The fate of human bodies, ships, etc., buried at sea.

Winchell, *Walks and Talks in the Geological Field:* 64–70, The sea bottom.

Special terms. Ooze, calcareous, mud, red clay, continental shelf, deeps.

81. OCEAN WATER

EXERCISE LIV. The Density and Temperature of Sea Water

Text-books. Davis, 62–65. Davis Ele., 100–102. Dryer, 250–255. Gilbert and Brigham, 286–288. Redway, 190–192. Tarr, 179–184.

Reference books. Shaler, *Sea and Land:* 106, The cause of the cold of the deep sea.

Special terms. Density, solution, salt.

82. WAVES

Text-books. Davis, 71–76. Davis Ele., 109–114. Dryer, 258–260. Gilbert and Brigham, 288–290. Redway, 194–196. Tarr, 184–187.

Reference books. Dodge, *Reader in Physical Geography:* 100–105, Wave erosion.

Shaler, *Outlines of the Earth's History:* 132–138[a], Waves.

Tarr, *Elementary Geology:* 221–231, Waves.

Special terms. Trough, crest, white cap, breaker, surf, undertow.

83. TIDES

EXERCISE LV. Tides

Text-books. Davis, 83–88. Davis Ele., 119–122. Dryer, 260–264. Gilbert and Brigham, 290–293. Redway, 197–200. Tarr, 187–190.

Reference books. Dodge, *Reader in Physical Geography:* 111–113, Tides.

Newcomb, *Elements of Astronomy:* 121–123, Tides.

Shaler, *First Book in Geology:* 122–124, Physiographic effects of tides.

Shaler, *Outlines of the Earth's History:* 126[b]–132, Tides.

Shaler, *Sea and Land:* 211[b]–213[a], Tides; 223–229, Effects of tides on harbors.

Tarr, *Elementary Geology:* 231–234, Tides.

Young, *Lessons in Astronomy:* 181–187, Tides.

Special terms. Gravitation, centrifugal force, high tide, low tide, slack water, spring tide, neap tide, ebb, flow, range of tide, bore.

84. OCEAN CURRENTS

EXERCISE LVI. Ocean Currents

Text-books. Davis, 77–83. Davis Ele., 114–119. Dryer, 264–270. Gilbert and Brigham, 294–297. Redway, 200–205. Tarr, 190–194.

Reference books. Dodge, *Reader in Physical Geography:* 108–111, Ocean currents.

Shaler, *First Book in Geology:* 102–106, Ocean currents.

Shaler, *Outlines of the Earth's History:* 145–148, The cause of ocean currents; 148–150, The Gulf stream; 150–152, The cold currents; 152–156, Climatic and other influences of ocean currents.

Tarr, *Elementary Geology:* 235–237, Ocean currents.

Special terms. Eddy, drift, stream, sargasso sea, equatorial current.

85. ICEBERGS, FLOES, PACKS

EXERCISE LVII. Icebergs

Text-books. Davis, 65–67. Davis Ele., 102–104. Dryer, 270–271. Gilbert and Brigham, 297–298. Redway, 162. Tarr, 194–195.

Reference books. Russell, *Glaciers of North America:* 83–86, Icebergs.

Shaler, *Outlines of the Earth's History:* 242[b]–243, Icebergs.

Shaler, *Sea and Land:* 115–123, Formation of ice floes; 123–132, Formation of icebergs; 133–139, Death of icebergs; 139–145, Climatic and physiographic effects of icebergs; 146–149, Beauty of icebergs; 148–152, Perils due to icebergs.

Special terms. Specific gravity, glacier, iceberg, floe, pack.

86. THE SEA AND MAN

EXERCISE LVIII. The Sea and Man

Text-books. Davis, 57–59, 73. Davis Ele., 97, 110–111. Dryer, 271–272. Gilbert and Brigham, 300–301, 315–318. Tarr, 15.

87. LIFE IN THE OCEAN

Text-books. Davis, 88–90. Davis Ele., 122–124. Dryer, 379–382. Gilbert and Brigham, 299–300, 343–345. Tarr, 195–198.

Reference books. Shaler, *Sea and Land:* 25–27, Animal and vegetable life along shore; 90–107, Life in the sea; 229–243, Marine life (vegetable) as related to harbors; 243–252, Marine life (animal) as related to harbors.

Winchell, *Walks and Talks in the Geological Field:* 69–70, Life in the sea.

Special terms. Seaweed, coral, calcareous, phosphorescence, blindness, commercial value.

CHAPTER XII

COAST FORMS

88. CONTINENTAL OUTLINES

Text-books. Davis, 70, 93–98. Davis Ele., 129–134. Dryer, 38–45. Gilbert and Brigham, 281. Redway, 42–46. Tarr, 22–28.

Reference books. Russell, *North America:* 1–16, The continental shelf of North America; 32–40, Changes in the coast line of North America due to waves and currents; 40–50, Changes due to oscillation of the land.

Shaler, *Sea and Land:* 62–66, 87[c]–89[a], Continental shelf.

89. ISLANDS

Text-books. Davis, 374–383. Davis Ele., 324–330. Dryer, 45, 174–177. Gilbert and Brigham, 282–286. Redway, 46–48. Tarr, 217–219, 222–223.

Reference books. Shaler, *Outlines of the Earth's History:* 84[b]–85[a], Islands.

Shaler, *Story of Our Continent:* 78–81, Islands near North America.

Special terms. Continental shelf, continental island, volcanic island, coral reef, atoll, stack.

90. ENCROACHMENT OF SEA ON LAND

EXERCISE LIX. Headlands, Beaches, Sea Caves

Text-books. Davis, 360–366. Davis Ele., 304–314, 314–322. Dryer, 229–231. Gilbert and Brigham, 302–310. Tarr, 210–212.

Reference books. Dodge, *Reader in Physical Geography:* 100–105, Wave erosion.

Heilprin, *The Earth and Its Story:* 104–106, Wear of the shore line.

Shaler, *Aspects of the Earth:* 130–134, Sea caves.

Shaler, *First Book in Geology:* 5–8, Sea pebbles; 15–19, Sand on the seashore; 86–87, Sea caves.

Shaler, *Outlines of the Earth's History:* 138[b]–145, The work of the "sea mill."

Shaler, *Sea and Land:* 8–12[a], Strong coasts; 15–20, Sea caves, natural bridges, etc.; 27–30, Weak coasts; 41[b]–46, Wearing of pebbles on a beach; 48, Beach wall.

Special terms. Strong shore line, weak shore line, headland, sea cliff, sea cave, bay, beach, abrasion, bowlder, pebble, sand.

91. ENCROACHMENT OF LAND ON SEA

EXERCISE LX. Barrier Beaches

Text-books. Davis, 369–376. Davis Ele., 322–327. Dryer, 231–238. Gilbert and Brigham, 310–313. Tarr, 212–220.

Reference books. Dodge, *Reader in Physical Geography:* 105–108, Wave deposits.

Heilprin, *The Earth and Its Story:* 106[c]–110, The ocean as a receiving basin.

Shaler, *First Book in Geology:* 20–23, Mud.

Shaler, *Sea and Land:* 49–52, Dunes of sea sand; 68–72, Barrier reefs and sea marshes; 86[b]–87, Coral reefs; 187–197, Sand reefs; 190[b]–192, Cause of sand reefs; 203–207, Coral reefs; 207[b]–209, Atolls; 233–243, Marine marshes.

Shaler, *Story of Our Continent:* 84–87, Barrier islands of the Atlantic and Gulf coast.

Tarr, *Elementary Geology:* 243–259, Deposition in the sea.

Special terms. Hook, spit, reef, bar, dune, delta, stratification.

92. RISING AND SINKING COASTS

EXERCISE LXI. Drowned and Elevated Coasts

Text-books. Davis, 357, 366–369. Davis Ele., 317–322. Dryer, 95, 227–229. Gilbert and Brigham, 313–314. Tarr, 204–210.

Reference books. Dodge, *Reader in Physical Geography:* 165–170, Movements of the land.

Fairbanks, *Western United States:* 75–85, History of a coast line.

Heilprin, *The Earth and Its Story:* 99–104, Inconstancy of oceanic and land levels; 199–202, Physiognomy of the coast line.

Russell, *Rivers of North America:* 217–221, Effects of subsidence.

Shaler, *Outlines of the Earth's History:* 91^b–96, Rising and sinking coasts.

Shaler, *Sea and Land:* 34^b–37, Rising coasts, old sea margins; 169–173, Rising and sinking coasts.

Shaler, *Story of Our Continent:* 81–84, Islands and inlets of northeastern North America.

Winchell, *Walks and Talks in the Geological Field:* 80–81, An Arabian narrative of rising and sinking coasts.

Special terms. Coastal plain, terrace, drowned lands, fiord.

93. COAST OUTLINES AND CIVILIZATION

Text-books. Davis, 196, 358–359. Davis Ele., 320–322, 368. Gilbert and Brigham, 315–318. Tarr, 203–204, 223–225.

Reference books. Shaler, *Sea and Land:* 154–161, Coast outlines and civilization.

94. HARBORS

EXERCISE LXII. Harbors

Text-books. Davis Ele., 120–122. Tarr, 223–225.

Reference books. Shaler, *Sea and Land:* 161^b–162, What makes a good harbor; 162–186, 187–222, 223–252, Harbors.

CHAPTER XIII

MINERALS AND ROCKS

95. ECONOMIC MINERALS AND ORES

EXERCISE LXIII. Economic Minerals and Ores

Text-books. Tarr, 408.

Reference books. Fairbanks, *Rocks and Minerals:* 103–106, Coal, graphite, diamond; 135–139, Gold; 140–144, Placer mining; 145–150, Iron; 151–153, Copper; 155–158, Silver; 159–162, Lead and zinc; 163–165, Tin; 166–167, Mercury or quicksilver; 170–171,

Platinum; 172–174, Aluminum; 178–180, Sulphur; 181–183, Gypsum; 193–194, Garnet; 195–196, Asbestos; 204–211, Salt; 212–215, Borax and soda.

Fairbanks, *Western United States:* 215–222, The life of the prospector; 223–232, Gold and gold mining; 233–240, Copper mining.

Heilprin, *The Earth and Its Story:* 207–209, Gold and silver; 209–213, Copper, zinc, tin, lead; 215–220, Iron; 220–224, Mercury, platinum, aluminum, sulphur; 225, Rock salt; 225–226, Gypsum.

Shaler, *Story of Our Continent:* 205–209[a], Importance of minerals in North America; 228–231, Methods of occurrence of gold; 222–224, Iron.

Tarr, *Economic Geology of the United States:* 144–146, Production of iron ore in the United States; 224–227, Production of copper in the United States.

Winchell, *Walks and Talks in the Geological Field:* 145–153, Down in a mine; 153–159, Iron and its geology; 159–165, Salt and gypsum.

96. ORGANICALLY FORMED ROCKS

EXERCISE LXIV. Limestone. LXV. Coal

Text-books. Davis, 102–103. Tarr, 410–411.

Reference books. Crosby, *Common Minerals and Rocks:* 23–30, Organic agencies in rock formation; 81–94, Chemically and organically formed rocks.

Fairbanks, *Rocks and Minerals:* 79–84, How animals and plants help to make the rocks; 85–86, Diatomaceous earth; 87–91, Limestone and marble; 92–96, Calcite and dolomite.

Fairbanks, *Western United States:* 241–246, Coal.

Heilprin, *The Earth and Its Story:* 23–26, Limestone and marble; 26–29, Coquina, chalk, ooze; 224–225, Graphite; 226–230, Coal.

Shaler, *First Book in Geology:* 38–45, Limestone; 46–55, Coal.

Shaler, *Story of Our Continent:* 38–44, The coal-making time in North America; 209–210[a], The origin of coal; 214–219, Distribution of coal in the United States.

Tarr, *Economic Geology of the United States:* 311–314, Coal; 314–321, Coal areas in the United States; 321–326, Origin of coal; 326–331, Conditions existing in Carboniferous times; 331–333, Uses of coal; 333–336, The production of coal.

Winchell, *Walks and Talks in the Geological Field:* 183–189, Solidified sunlight — coal and coal beds; 214–220, Lone burials in the coal lands.

97. PETROLEUM AND NATURAL GAS

Reference books. Fairbanks, *Rocks and Minerals:* 97–102, The story of petroleum.

Fairbanks, *Western United States:* 246–248, Petroleum.

Heilprin, *The Earth and Its Story:* 230–231, Petroleum and natural gas.

Shaler, *Story of Our Continent:* 210–211, Petroleum and rock gas; 219[c]–222[a], Distribution of petroleum, oil, and gas in North America.

Tarr, *Economic Geology in the United States:* 340–346, Origin of petroleum; 346–347, Uses of petroleum; 347–349, Production of petroleum; 351[a]–355, Natural gas; 355–357, Asphaltum.

Winchell, *Walks and Talks in the Geological Field:* 166–172, Liquid sunlight — petroleum; 173–183, Gaseous sunlight — natural gas.

98. FOSSILS

Reference books. Crosby, *Common Minerals and Rocks:* 141–147, Ripple marks, fossils.

Fairbanks, *Rocks and Minerals:* 76–78, How wood changes to stone.

Heilprin, *The Earth and Its Story:* 38–39, Fossil imprints in the rocks; 150–153, Fossils.

Shaler, *First Book in Geology:* 189–194, How fossils are formed.

Shaler, *Sea and Land:* 121[b]–124, Forests silicified while buried in sand.

Ward, *Report on the Petrified Forests of Arizona:* 9–10, Scenic features; 10–11, Location of the petrified forests; 11–17, Geological considerations; 17–19, Preservation of the petrified forests; 22–23, Recommendations.

Winchell, *Walks and Talks in the Geological Field:* 78–81, Fossils; 189–197, Monsters of a buried world; 206–214, Lessons from chalk.

99. IGNEOUS ROCKS

EXERCISE LXVI. Granite

Text-books. Dryer, 34–36. Gilbert and Brigham, 6–7, 76–78. Tarr, 33–34, 406–407, 411–412.

Reference books. Crosby, *Common Minerals and Rocks:* 111–114, Plutonic or dike rocks.

Fairbanks, *Rocks and Minerals:* 27–33, What we find in granite; 34–37, How granite decays; 70, Use of quartz.

Heilprin, *The Earth and Its Story:* 30–32, Granite.

Shaler, *First Book in Geology:* 12–15, Sand.

Winchell, *Walks and Talks in the Geological Field:* 39–44, Kinds of minerals and rocks.

100. FRAGMENTAL ROCKS

EXERCISE LXVII. Fragmental Rocks

Text-books. Davis, 101–102. Dryer, 32–34. Gilbert and Brigham, 74–76. Tarr, 409.

Reference books. Crosby, *Common Minerals and Rocks:* 72–80, Fragmental rocks; 129–137, Stratification; 137–140, Overlap, etc.

Fairbanks, *Rocks and Minerals:* 47–51, How rocks are made; 53–55, Three kinds of sedimentary rocks.

Heilprin, *The Earth and Its Story:* 20–23, Sandstone and pebble rock; 39–43, Stratification, folding, dip; 29–30, Flags, shales, slates.

Shaler, *First Book in Geology:* 30–33, Conglomerate; 34–35, Sandstone; 36–37, Mud stones.

Winchell, *Walks and Talks in the Geological Field:* 44–45, Sedimentary rocks; 71–77, Strata and their classification.

101. METAMORPHIC ROCKS

Text-books. Dryer, 35–36. Tarr, 34, 413.

Reference books. Crosby, *Common Minerals and Rocks:* 30–34, Igneous agencies; 95–108, Metamorphic rocks.

Fairbanks, *Rocks and Minerals:* 56–58, Slate, mica schist, and quartzite.

Heilprin, *The Earth and Its Story:* 33–35, Gneiss and schists.

102. BUILDING STONE

EXERCISE LXVIII. Building Stone

Reference books. Heilprin, *The Earth and Its Story:* 232–238, Building stone.

Tarr, *Economic Geology of the United States:* 359–360, What stones are used for building purposes; 383–384, Building-stone production in the United States.

CHAPTER XIV

WEATHERING AND SOILS

103. DECOMPOSING AGENTS

EXERCISE LXIX. Decomposing Agents

Reference books. Bailey, *Principles of Agriculture:* 16–22, What soil is and how it is made.

Crosby, *Common Minerals and Rocks:* 10[b]–14, Chemical erosion.

Heilprin, *The Earth and Its Story:* 13–17, The decay of rocks.

Jordan, *Science Sketches:* 232–255, An ascent of the Matterhorn.

Russell, *Rivers of North America:* 2–3, Mechanical disintegration; 236–240, Vegetation hastens weathering.

Shaler, *Aspects of the Earth:* 300–309, Agents of soil formation.

Shaler, *First Book in Geology:* 3[b]–4, Frost as a weathering agent; 21[b]–23, Oxygen, acids, worms, roots, as weathering agents.

Shaler, *Outlines of the Earth's History:* 315[b]–321[a], Effect of organic life on soil.

Shaler, *Sea and Land:* 21–26, Weathering agencies along shore.

Tarr, *Elementary Geology:* 109–119, Decomposing agents; 128, Summary of weathering.

Winslow, *Principles of Agriculture:* 30–35, The soil.

104. KINDS OF SOIL

Reference books. Bailey, *Principles of Agriculture:* 22–25, Transportation of soil.

Dodge, *Reader in Physical Geography:* 73–76, The effects of gravity in soil making; 201–203, Kinds of soil.

Heilprin, *The Earth and Its Story:* 238–240, Clays and soils.

King, *Irrigation and Drainage:* 269–274, Alkali lands; 280–289, Treatment and use of alkali lands.

Shaler, *Aspects of the Earth:* 317–329, Kinds of soil and soil zones.

Shaler, *First Book in Geology:* 24–29, Soils.

Shaler, *Outlines of the Earth's History:* 322[b]–327, Transported soil.

Shaler, *Story of Our Continent:* 183–190, Glacial, residual, alluvial soils; 190–192, Alkali land.

Tarr, *Economic Geology of the United States:* 391–394, Residual or indigenous soils; 394–396, Transported soils; 396–398, Glacial soils; 399–402, Clays.

Tarr, *Elementary Geology:* 120–121, Residual soil and soil zones.

Winslow, *Principles of Agriculture:* 35–39, The composition of the soil.

105. FERTILITY OF THE SOIL

Reference books. Bailey, *Principles of Agriculture:* 25–36, The resources of the soil; 37–46, The texture of the soil; 47–50, 57[c]–59[a], Moisture in the soil; 50–57, 59[b]–63, Increase and conservation of moisture in the soil.

Brigham, *Geographic Influences in American History:* 46[c]–50, Barren soil and abandoned farms of New England.

Dodge, *Reader in Physical Geography:* 198–201, Soils; 204–205, Fertility of soils.

Shaler, *Aspects of the Earth:* 329–339, Fertility of the soil.

Shaler, *Outlines of the Earth's History:* 327[b]–331[a], Conditions of fertility of soil; 343–348, How cultivation injures soil.

Shaler, *Story of Our Continent:* 6[c]–9[a], Fertility of the soil.

Tarr, *Economic Geology of the United States:* 398–399, Wearing out of soils by cultivation.

Winslow, *Principles of Agriculture:* 77–80, Fertile soil; 80–83, Elements which generally fail soonest.

106. FERTILIZERS

Reference books. Bailey, *Principles of Agriculture:* 64–76, The tillage of the soil.

Heilprin, *The Earth and Its Story:* 240–241, Lime, guano, phosphates.

Moore, *Bacteria and the Nitrogen Problem:* 333–342, Bacteria and the nitrogen problem.

Tarr, *Economic Geology of the United States:* 402–412, Fertilizers.

Winslow, *Principles of Agriculture:* 83–89, Artificial and prepared fertilizers; 89–97, Methods of applying fertilizers; 100–107, Cultivation; 108–110, Draining; 110–112, Rotation of crops.

107. IRRIGATION

EXERCISE LXX. Irrigation

Reference books. Fairbanks, *Western United States:* 259–267, Irrigation.

King, *Irrigation and Drainage:* 66–72, Antiquity of irrigation; 72–77, Irrigation in Europe; 77–84, Irrigation in Asia; 84–85, Irrigation in Egypt; 88–89, Summary of extent of irrigation; 239–241, Units of measurement of water; 290–296, Diverting river water, Punjab, India; 296–304, Diverting river water, Redlands, California; 328, Use of animal power for lifting water; 338–344, Irrigation by flooding; 352–359, Field irrigation by furrows; 373–381, Orchard irrigation; 396–402, Subirrigation.

King, *The Soil:* 268–275, Irrigation.

Kinney, *Forest and Water:* 189, Measurement of water; 229–233, Variation in stream flow; 191–198, Methods of irrigation.

Meade, *Irrigation Institutions:* 100–113, Measurement of water.

108. FORESTRY AS RELATED TO THE SOIL

Reference books. California Water and Forest Association, *Should the Forests be preserved?* 7–13, Forestry and irrigation; 18–21, How forests prevent floods; 22–27, Forests and water storage.

Gifford, *Practical Forestry:* 46–51, The forest as a soil former; 51–56, The forest as a soil improver; 56–58, The forest as a soil

fixer; 58-63, The forest as a flood preventer and a conservator of moisture.

Kinney, *Forest and Water:* 22, Advantages of forested watersheds; 78–85, Torrents; 91–97, Control of torrents; 174–177, Forests increase rainfall and conserve moisture; 185–186, Forests prevent evaporation.

Roth, *A First Book of Forestry:* 203–209, The forest as a protective covering.

Russell, *Rivers of North America:* 236–240, Forestry.

Shaler, *Aspects of the Earth:* 259–261, Forests enrich the soil; 270–275, Forests prevent floods and increase rainfall; 290–293, Underground work of forests.

Toumey, *Relation of Forests to Stream Flow:* 279–288, The relation of forests to stream flow.

CHAPTER XV

PLANTS, ANIMALS, AND MAN

109. CONDITIONS OF LIFE

Text-books. Davis Ele., 332–337. Dryer, 349–351. Gilbert and Brigham, 332–338. Redway, 303–308. Tarr, 336–339, 353–354.

Reference books. Coulter, *Plant Studies:* 169–175, The environment of a plant.

Jordan and Kellogg, *Animal Life:* 106–113, The primary conditions of animal life.

Pinchot, *Primer of Forestry,* Part I: 7–24, The life of a tree; 25–43, Trees in the forest.

Osterhout, *Experiments with Plants:* 326–343, How plants are influenced by water; 344–348, How plants are influenced by light; 348–349, How plants are influenced by wind; 349–351, How plants are influenced by food; 352–360, How plants are influenced by heat.

Winslow, *Principles of Agriculture:* 55–57, Conditions of growth; 61-62, Plants purify the air; 65-68, Food from soil; 71–73, Sap, nutrition, selection.

110. PLANT ZONES

Text-books. Davis, 319–321. Davis Ele., 353–357. Dryer, 351–359. Gilbert and Brigham, 323–328. Redway, 315–317. Tarr, 339–344.

Reference books. Bergen, *Foundations of Botany:* 307–323, Plant societies; 324–335, Botanical geography.

Coulter, *Plant Studies:* 177–187, Water plants; 188–213, Drouth plants; 214–220, Plants requiring moderate water supply.

Merriam, *Life Zones and Crop Zones of the United States:* 18–53, Life zones of the United States.

Roth, *A First Book of Forestry:* 37–40, The woods and the mountains.

Russell, *North America:* 254–257, The treeless mountain tops.

111. THE DISTRIBUTION OF ANIMALS

Text-books. Davis, 105–111. Davis Ele., 338–349. Dryer, 364–382. Gilbert and Brigham, 328–331, 343–345. Redway, 324–328. Tarr, 354–359.

Reference books. Bailey, *Handbook of Birds of the Western United States:* xxxiii–xxxvi, Life zones.

Jordan and Kellogg, *Animal Life:* 296–306, Fauna and faunal areas.

Russell, *North America:* 264–292, Some representative mammals of North America.

Shaler, *Story of Our Continent:* 196–205, Animals of North America.

112. MIGRATIONS AND BARRIERS

Text-books. Davis, 54–56. Davis Ele., 333–334. Dryer, 359–360. Gilbert and Brigham, 340–343. Redway, 309–313. Tarr, 345–346, 360–364.

Reference books. Bailey, *Handbook of Birds of the Western United States:* xxxvi–xxxvii, Migrations.

Beal, *Seed Dispersal:* 4–11, Plants spread by means of roots; 12–17, Plants multiply by means of stems; 18–29, Water transportation of plants; 30–56, Seeds transported by wind; 58–60,

Plants that shoot off their seeds; 61–79, Plants that are carried by animals; 80–83, Man disperses seeds and plants; 84–87, Some reasons for plant migration.

Bergen, *Foundations of Botany:* 373–386, How plants are scattered.

Coulter, *Plant Studies:* 112–122, Dispersal of plants.

Jordan, *Science Sketches:* 263b–266, How the trout crossed the Rocky mountains into Yellowstone lake; 267–278, How the trout came to California.

Jordan and Kellogg, *Animal Life:* 272–283, Laws of geographical distribution; 283–288, The relation of species to habitat; 288–296, Character of barriers to distribution.

Osterhout, *Experiments with Plants:* 320b–325, How seeds are scattered.

Russell, *North America:* 292–298, Migration of animals.

113. CHANGES IN PLANTS AND ANIMALS

Text-books. Davis Ele., 335–338. Dryer, 360–363. Gilbert and Brigham, 339–340. Tarr, 346–348, 364–365.

Reference books. Bergen, *Foundations of Botany:* 387–395, The struggle for existence and the survival of the fittest.

Coulter, *Plant Studies:* 142–148, The struggle for existence.

Dodge, *Reader in Physical Geography:* 119–120, Effects of cold and frost on life.

Heilprin, *The Earth and Its Story:* 156–158, The variation and extinction of animal forms.

Jordan, *Science Sketches:* 9–19, The story of a salmon.

Jordan and Kellogg, *Animal Life:* 114–122, The crowd of animals and the struggle for existence.

Osterhout, *Experiments with Plants:* 409–417, Mr. Burbank's work with plums; 422–427, Mr. Burbank's work with the Shasta daisy; 429–434, Methods and difficulties of crossing and selection; 434–441, Experiments with corn at the Illinois Experiment Station.

Pinchot, *Primer of Forestry,* Part I: 44–66, The life of a forest.

Shaler, *First Book in Geology:* 195–202, How species are made.

Shaler, *Sea and Land:* 100[b]–104, The struggle for existence and the origin of species.

Shaler, *Story of Our Continent:* 14–17, A progression of forms of life.

114. ECONOMIC VALUE OF PLANTS AND ANIMALS

Text-books. Dryer, 385. Redway, 317–324, 328–331. Tarr, 348–350, 365–366.

Reference books. Bailey, *Handbook of Birds of the Western United States:* xxxvii–xxxix, Economic ornithology; xxxix–xliii, The protection of birds.

Bailey, *Principles of Agriculture:* 106–111, The offices of the plant; 201–207, The offices of the animal.

Merriam, *Life Zones and Crop Zones of the United States:* 9–17, Relations of the United States Biological Survey to practical agriculture.

Roth, *A First Book of Forestry:* 133–134, Use of the forest; 136–150, Firewood, pulp, posts, railway ties, etc.; 174–177, Resin and turpentine, seeds and mast; 178–182, Pasturage, game, and fish; 198–202, Sand dunes checked by forests.

Shaler, *Story of Our Continent:* 193–196, Domesticated plants of North America.

Winslow, *Principles of Agriculture:* 61–62, Plants purify the air.

115. FORESTS

Text-books. Dryer, 352–359. Gilbert and Brigham, 319–323. Tarr, 349–350.

Reference books. Brigham, *Geographic Influences in American History:* 279–285, Forestry a federal question; 341[c]–346, The work of the United States Bureau of Forestry.

Fairbanks, *Western United States:* 278–289, Forest belts of the Sierra Nevada mountains; 290–302, National parks and forest reserves.

Muir, *Mountains of California:* 247–254, A windstorm in the forest.

Pinchot, *Primer of Forestry,* Part I: 67–88, Enemies of the forest.

Pinchot, *Primer of Forestry*, Part II: 7–37, The practice of forestry; 38–55, Work in the woods; 56–73, The weather and the streams; 74–88, Forestry abroad and at home.

Roth, *A First Book of Forestry:* 14–18, What light and shade do for the woods; 18–24, What different soils do for the woods; 24–32, What moisture does for the woods; 32–37, What heat and cold do for the woods; 37–40, The woods and the mountains; 41–45, Use not abuse of the woods; 104–112, Protection against fire; 195–198, Forest plantations on prairies; 209–214, Forests of our own country; 214–216, Some history.

Russell, *North America:* 215–218, The forests of North America; 219–227, The tropical forests; 227–235, The Atlantic forest; 235–237, The boreal forest; 238–249, The Pacific forest.

Shaler, *Outlines of the Earth's History:* 341[b]–343[a], Why prairies are treeless.

Shaler, *Story of Our Continent:* 112–121, Forests of North America.

116. NATURE AND MAN

Text-books. Davis, 1–7. Davis, Ele., 349–353. Dryer, 383–385. Gilbert and Brigham, 346–359. Redway, 335–336. Tarr, 369–375.

Reference books. Shaler, *Story of Our Continent:* 153–157, Indians of North America; 157–161, Indian civilization; 161–165, Geographical hindrances to Indian civilization; Dodge, *Reader in Physical Geography:* 213–221, Defense, etc.

Fairbanks, *Western United States:* 176–186, The Cliff Dwellers and their descendants.

Harrington, *About the Weather:* 1–8, Man's conquest of nature takes several forms; 9–16, Civilization has many disadvantages, especially physical.

117. GEOGRAPHICAL FACTORS IN THE LIFE OF CIVILIZED PEOPLES

Text-books. Davis, 113–116. Davis Ele., 364–372. Dryer, 390–392. Gilbert and Brigham, 315–318, 359–370. Redway, 347–349, 352–372. Tarr, 375–380, 384–392.

Reference books. Brigham, *Geographic Influences in American History:* 18–22, The Erie canal; 22–24, Railroads in the Mohawk valley; 24–25, The railroads across the Appalachians; 25[b]–28, Geographic conditions favorable to New York city; 50[b]–52, Water power for New England cities; 86–89, Effect of the Appalachian barrier on colonial and Revolutionary history; 105–115, Historical importance of the Great Lakes; 126–141, Importance of commerce of the Great Lakes; 160–172, Physiography and commercial allegiance of the prairie country; 259–263, Natural causes for the development of towns in Colorado.

Dodge, *Reader in Physical Geography:* 28–32, Centers of life; 33–46, Agricultural centers, grazing centers, lumbering centers; 47–58, Manufacturing, mining, fishing, hunting, and scenic centers; 194–197, Climate of the world — seasons and summary; 206–212, Water supply; 222–227, Transportation and power.

Fairbanks, *Western United States:* 205–214, How climate and physical features influenced the settlement of the West; 268–277, Location of cities of the Pacific slope.

Russell, *North America:* 365–376, The Eskimos, the Innuits, the Aleutians; 376–384, The Indians, resources and natural food supply; 384–394, Horticulture and houses of the Indians; 396–406, The contact of the aborigines with foreign peoples.

Shaler, *Story of Our Continent:* 9–12, Life of man modified by geographical conditions; 161–165, Geographical hindrances to Indian civilization; 233–245, Effects of the form of North America; 246–253, Commerce of North America; 262–278, The natural conditions of North America which affected its settlement by Europeans; 166–169[a], Influence of soil, climate, etc.

118. DISTRIBUTION AND RACES OF MEN

Text-books. Dryer, 385–390. Redway, 336–347. Tarr, 381–383.

Reference book. Dodge, *Reader in Physical Geography:* 228–231, Historical distribution of people.

Part II

FIELD AND LABORATORY MANUAL

FIELD AND LABORATORY MANUAL

EXERCISE I

MAGNITUDES AND DISTANCES

The following table gives approximately, in miles, the distance of each of the eight planets from the sun, the diameter of each planet, and the diameter of the sun.

	Diameter	*Distance*
Sun . . .	800,000	0
Mercury . .	3,000	36,000,000
Venus . .	7,600	67,000,000
Earth . . .	8,000	93,000,000
Mars . . .	4,200	141,000,000
Jupiter . .	80,000	480,000,000
Saturn . .	70,000	881,000,000
Uranus . .	31,000	1,772,000,000
Neptune . .	34,000	2,770,000,000

Using the diameter of the earth given above, find the circumference. How long would it take an express train to go this distance at the rate of 50 miles per hour? In a similar manner find the circumference of the sun. How long would it take the express train just mentioned to travel this distance? Using the scale of 200,000 miles to the inch, draw a circle to represent the sun. Use the same scale and draw a circle at the center of the sun to represent the earth. The moon is about 240,000 miles distant from the earth. Place a dot at the proper point to represent this. Imagine the earth located as you have drawn it, at the center of the sun, and take an imaginary trip from the earth to the surface of the sun. After reaching the moon, how much farther would you have to go?

The volumes of two spheres are to each other as the cubes of their respective diameters. How many earths would it take to make one sun? Jupiter is the largest of the planets. How many earths would it take to make a Jupiter?

Draw on the blackboard a circle to represent the sun, using the scale of 1,000,000 miles to the inch. How large is the circle? Use the same scale and place a dot to represent the distance between the sun and Mercury; between the sun and Venus; between the sun and the earth. Make the dot for the earth very small; it should not be as large as a period used in printing on this page. Place very small dots to represent the positions of the other planets. Are there any planets whose positions you cannot represent? Why? Imagine yourself standing on the sun and looking at the planets; which is more striking, the sizes of the planets or the distances in space?

If you were to represent the position of the nearest fixed star according to the scale last used, you would need 300 miles of blackboard. Light travels at the rate of 186,000 miles per second. If light could travel in a circular path, how many times could it go around the earth in a second? At this rate how long would it take light to travel from the sun to the earth? How long from the sun to Neptune? At the same rate it would take the light of the nearest fixed star three years to reach the earth. How far is it to the nearest fixed star? This is how many times as far as it is from the earth to the sun? Think of this at night when you look at the stars.

EXERCISE II

THE OBLATENESS OF THE EARTH

Fasten a weight, as a small stone or heavy bullet, to a string and whirl it with the hand as nearly as you can round a fixed point on the table top or on the floor. What is the shape of the path? Trace the path with a chalk line. Does the whirling weight pull on the string. Whirl it rapidly. Is the strength of

the pull increased or decreased? Whirl it rapidly enough to break the string. What becomes of the weight? Trace its path with a chalk line. What shape is its path? What relation does it sustain to the former path? The force which drives it along the latter path is called *centrifugal* ("fleeing-from-the-center") force. In what direction with reference to the circumference does centrifugal force act on a whirling body?

What force acted upon the moving weight before the string broke, which did not act after it broke? What relation does the direction of this force sustain to the circle? This force is called *centripetal* ("seeking-the-center") force. When these two forces, centrifugal and centripetal, act at the same time, what kind of motion may result? Make a drawing in your notebook similar to the one drawn in chalk. Place arrows to show the direction of the motion. Place the words *centrifugal* and *centripetal* on the proper lines to represent the directions of these forces.

Use the rotating machine and brass rings. Cause the rings to rotate slowly. What shape is the form which appears? Which part is moving more rapidly, the part near the axis or the part midway between the poles? In which part is centrifugal force greater? Cause the rings to rotate rapidly. What effect has this increase of speed upon the centrifugal force midway between the poles? What change is there in the shape of the resulting form? Account for this difference in shape. Make a drawing to show the shape when rotating slowly and another to show the shape when rotating rapidly. Indicate by title which is which.

How do you know that the earth is flattened at the poles? How was the fact discovered? Explain how it may have obtained this shape. Have we proved that it obtained its shape in this way? If this theory is the correct one, in what condition was the mass of the earth at the time it assumed its present form?

What name is given to the centripetal force in the case of the earth's rotation? What evidence have we that the earth is rotating at the present time?

EXERCISE III

THE DIRECTION OF THE AXIS OF THE EARTH'S ROTATION

Suspend the gyroscope[1] by a string. Carefully balance it and cause it to rotate rapidly. Carry it around in a circular path. What is the direction of the axis when at the south side of the circle? at the east side? at the north side? at the west side? Repeat the experiment to be sure that your results are not accidental. What relation does the direction of the axis in one position sustain to the direction in any other position?

Grasp the gyroscope firmly by the handle and cause it to rotate rapidly. Hold it with the axis pointing east and west; then quickly turn it so that the axis points north and south. Repeat this several times. Can you readily change the direction of its axis of rotation?

Observe a star or constellation in the east soon after sunset, and again after two or three hours. What change has occurred? What is the cause of this change? Observe the same star again during the night, and again the next evening soon after sunset. Are you able to see the whole of its path? Why?

Observe a star in the north, very near the horizon, and again several times during the night. What change has occurred? What is the cause of the change? What is the shape of the apparent path of the star? Can you see the whole of its path? Is there a star that does not have this apparent motion? Account for this. Describe the direction of the earth's axis with reference to the stars. Does the axis always retain this direction? How do you know?

Do you see any similarity between the movements of the earth and those of the gyroscope?

[1] The gyroscope may be homemade by mounting a small heavy wheel on an axis. A bicycle wheel with ball bearings is suggested.

EXERCISE IV

LENGTHS OF DAY AND NIGHT

Carry a globe in a circle round a pupil who will represent the sun. From data so obtained, define *orbit* and *plane of orbit*. Place the axis of the globe perpendicular to the plane of the orbit and carry the globe round again. Adjust a pasteboard circle so that it will exactly bound the illuminated portion of the globe and thus separate the illuminated portion from the dark portion. An imaginary circle which does this is called the *circle of illumination*. Cause the globe to rotate. Compare the period of time required for some point on its surface, say your own town, to pass through the illuminated portion with the period required to pass through the dark portion.

What angle does the axis of the earth form with the plane of its orbit? (See the text-books.) What angle does it make with the perpendicular to the plane of the orbit? Place the globe with its axis in this position. Find a place in the orbit where the lengths of day and night are equal (first position). Move the globe from this position through one fourth of the orbit (second position). Be sure that the pasteboard circle is properly adjusted. Compare the period of time that it now takes your town to pass through the illuminated part with the period required to pass through the dark part. Does the circle of illumination now cut your circle of latitude into equal or unequal parts? Compare the "day" part with the "night" part. Find another position (third position) in the orbit where the days and nights are equal in length. Describe this position with reference to the first. Find a position (fourth position) in the orbit where the relative lengths of day and night are the reverse of what they are in the second position. Compare the relative parts into which the circle of illumination cuts your circle of latitude with the relative lengths of day and night. At what time of year do you find conditions existing similar to those of the first position? the third position? the second position? the fourth position? Give names to these particular times of the year.

EXERCISE V

NORTH AND SOUTH LINE

Set a post in the ground so that the top will be about two feet above the surface. A broomstick makes a good post. By means of a plumb line make this post vertical, and with it as a center draw a circle on the ground with a radius of 57.3 inches. What is the circumference of this circle? How many degrees are there in a circle? What is the length of one degree of this circle?

What direction is taken by the first shadow which is cast by the post in the morning? Give direction and length of shadow at 9 A.M.; at noon; at 3 P.M. What change in the length of the shadow occurs in the forenoon? in the afternoon?

At some time in the forenoon the end of the shadow will cross the circumference of the circle. Mark the point where it just touches the circumference. Do the same in the afternoon. Connect these two points with a straight line. This line is due east and west. Divide it exactly in the middle. Draw a line from this middle point to the center of the post. Extend the last line until it cuts the circumference on opposite sides. What angle does the last line form with the first? In what direction does the last line extend? Draw a line due east and west through the center of the post. Make a drawing to show the circle, the position of the post, and the lines. Use letters to indicate directions.

At night observe the north star and place a mark on the circumference so that the mark, the post, and the north star shall be in a straight line. From this point draw a diameter. In what direction does the diameter extend? If this line does not coincide with the other north and south line, account for the difference. Do you know of any other method by which you might determine true north?

EXERCISE VI

THE APPARENT MOVEMENTS OF THE SUN

Part I

Use the circle drawn in Exercise V. Stand so that the center of the post is between you and the point of sunrise. Make a mark on the circumference of the circle, such that it will be in line with the point of sunrise and the post. Is the point of sunrise due east? If not, how many degrees north or south of due east is it? (Should you find the point of sunrise 5 degrees south of due east, its direction would be read "east, 5 degrees south.") Make a similar observation for sunset. When the sun is due south it is said to be on our meridian, and we call the hour *noon*. By the use of the clinometer (Fig. 1) determine the angle of elevation of the sun when it is on our meridian. (The *angle of elevation* is the angle that a ray of light from the sun makes with the plane of the horizon.) Set your watch by the sun at noon and from that determine the exact times of sunrise and sunset. From this determine the length of the day from sunrise to sunset.

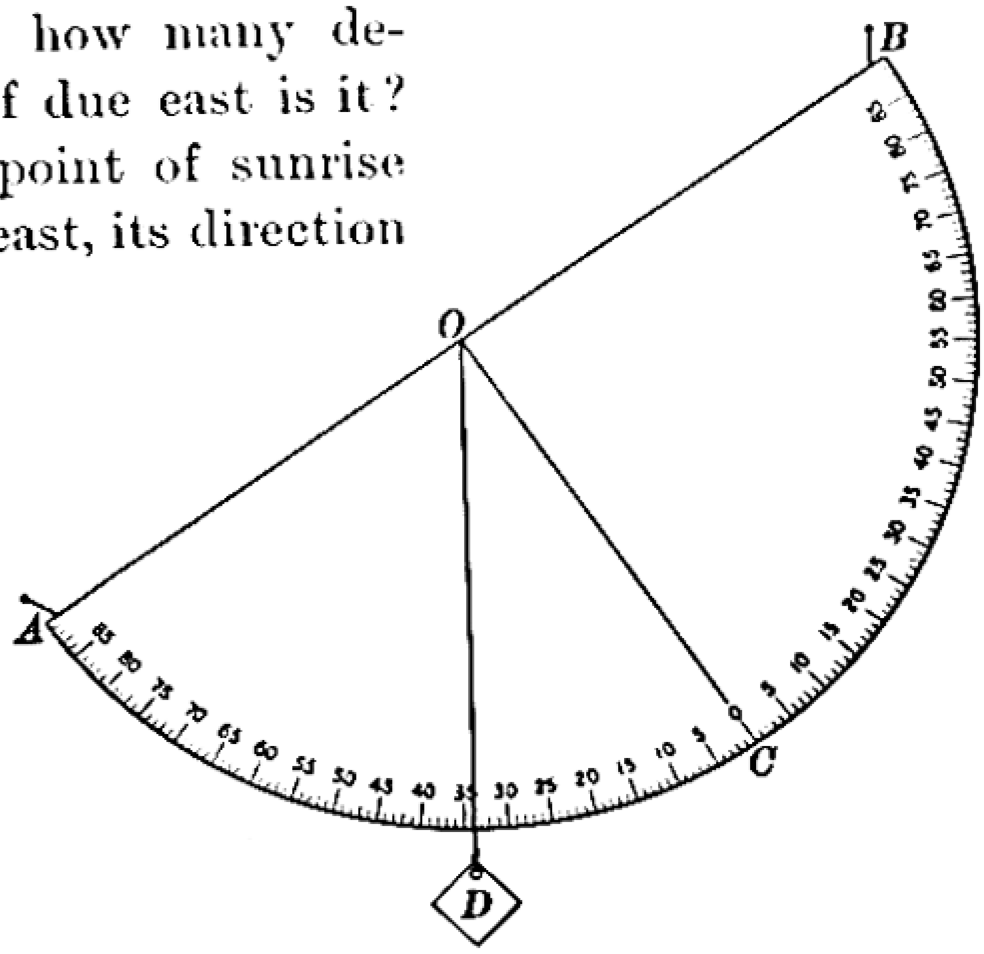

Fig. 1. The Clinometer

When the clinometer is held so that the line AB is horizontal, the vertical line DO coincides with the line CO. When it is used to determine a vertical angle, AB is pointed at the object of observation. DO then departs from CO as much as AB does from the horizontal, hence angle COD is the angle of elevation

In determining the angle of elevation of the sun, hold the clinometer so that the shadow of the pin at A or at B falls on the line AB. Angle COD is then the desired angle

Make observations similar to the preceding every two weeks and tabulate your results, giving, in different columns, (*a*) date, (*b*) direction of sunrise, (*c*) direction of sunset, (*d*) time of sunrise, (*e*) time of sunset, (*f*) length of day, (*g*) elevation of the sun at noon.

Part II

When is the day longest? When shortest? When are days and nights of equal length? How many times each year are the days and nights of equal length? Is the sun ever directly over your head? Is it ever north of you at noon? At what time of day does the sun shine on the north side of the house? Explain how this can be. During what months do you find the greatest difference between successive readings in the second and third columns of your table? Compare this with the times of the equinoxes and the solstices.

Part III

Carry a globe in a circular path about a pupil, who will represent the sun. Adjust the globe so that the axis shall be perpendicular to the plane of its orbit. What then is the angle of noon elevation of the sun to an observer at the equator? Hold a card tangent to the globe at 40 degrees north latitude on the side nearest to the sun, to represent the plane of the horizon of an observer at that point. What is the angle of noon elevation of the sun to an observer at this point? (All the rays of light which reach the earth from the sun are practically parallel. Consider their direction as parallel to a line joining the center of the sun and the center of the earth.) Cause the earth to revolve about the sun. Note and record any change in the angle of noon elevation of the sun.

Adjust the globe so that the axis shall be inclined 20 degrees from the perpendicular. What is the angle of noon elevation of the sun at the time of the equinox to an observer at the equator? to an observer at 40 degrees north latitude? Cause the earth to revolve about the sun. The greatest angle of noon

elevation of the sun is made at the time of the summer solstice. Determine and record this angle. When is the smallest angle made? Determine and record this angle. What is the difference (in degrees) between the greatest and the smallest angle? Compare this with the angle of inclination (20 degrees).

Repeat this part of the experiment, having the axis of the earth inclined 40 degrees from the perpendicular, and make the same comparison as before. Give a rule for determining the difference between the greatest and the smallest angle (noon elevations), when the angle of inclination of the earth's axis is given. Give a rule for determining the angle of inclination of the earth's axis, when you have the greatest and the smallest angle of noon elevation of the sun. Apply this rule to the noon elevations given in your table and determine the true angle of inclination of the earth's axis. Compare this with the angle given by the books.

PART IV

Use cross-section paper and mark out a rectangle 26 squares long and 24 squares wide. Draw a line lengthwise through the center of the rectangle. Let each square lengthwise represent two weeks of time. Write opposite each line a date from your table of observations. Let each square crosswise represent an hour of the day. Let the line through the center represent noon. Place figures to indicate the hour represented by each line. Distinguish between forenoon and afternoon. Place a dot at the proper point to represent the hour of sunrise on the date of your first observation. Do the same for the hour of sunset. Make dots in the proper positions for all other observations recorded in the table. In like manner represent the times of sunrise and sunset for that portion of the year not included in your table. (Use the almanac.) Draw a line through as many of the sunrise dots as possible, to make a somewhat regular curve. We call this line the *sunrise curve*. Draw the *sunset curve*. Shade the night portion of your diagram, leaving the day portion white. Give the completed diagram the title "Sunset and Sunrise Curves from — to —," giving the dates.

EXERCISE VII

THE MOON

Refer to the almanac, determine the date of the next new moon, and look for it on the evening of that day. If you do not see it, look again the next evening. Make a drawing of the moon as it appears when you first see it. Observe the moon at sunset two days later and make a drawing. Make a drawing every two days until the moon is full. Give your drawings a title, giving in each case the age of the moon in days, counting from the date of the new moon. In what part of the heavens did you first see the new moon? What change in position occurs on successive evenings? In what direction does the moon move round the earth? How do you know? In what length of time does the moon make one revolution round the earth? (Calculate the exact time in days, hours, minutes, and seconds from one new moon to the next succeeding, as given in the almanac.)

Place a slated globe on the table and whiten the side which would be illuminated by the setting sun, if its light could fall on the globe. How much of the surface of the globe would be illuminated? Let this globe represent the moon and allow one pupil to carry it entirely round the room, always keeping the white side toward the direction of the setting sun. How much of the surface is illuminated when the globe is south of you? How much of the illuminated part can you see? What phase of the moon does this represent? How much of the surface is illuminated when the globe is east of you? How much of the illuminated part can you see? What phase does this represent? In which direction from you is the globe when it represents the new moon?

Make a drawing to represent the surface of the moon as seen through the telescope.

EXERCISE VIII

LATITUDE

If you were at the equator, where would the sun appear at noon at the time of the equinox? What would be its noon elevation in degrees? Where would the sun appear at this time if you were at the north pole? (Remember that the sun is so remote from the earth that rays coming to the pole are practically parallel with those coming to the equator.) What would be the sun's noon elevation at the north pole? What would be its noon elevation if you lived 30 degrees north of the equator? If its noon elevation were 50 degrees, what would be your latitude? Give a rule for finding your latitude from the noon elevation of the sun at the time of the equinox. From your table of observations (Exercise VI) determine your latitude according to this rule. If the result is not correct, account for your error. Is your rule correct for noon elevations taken at any time of the year? Give a reason for this.

Use the clinometer and take the elevation of the north star. Compare this with your latitude. What change would occur in the elevation of the north star if you should go toward the north pole? Where would it appear if you should reach the north pole? What would then be its elevation? What is the latitude of the north pole? What is the latitude of the equator? What would be the elevation of the north star at the equator? Where would the north star appear to one living in the southern hemisphere?

Where does the line of your latitude strike Europe? What places in North America are in the latitude of London, England?

If a straight line were drawn from your home through the center of the earth, in what latitude would it pierce the surface on the opposite side? In what longitude would this be? Examine the globe to see if your answers are correct.

If you were to go due south from St. Louis, Missouri, to the South Pole, over what land and through what waters would you pass? Name another town approximately in the longitude of New York; of Tokio; of Cape Town.

EXERCISE IX

SOME PROPERTIES OF THE ATMOSPHERE

Part I

Aim. To ascertain whether air has weight.

Apparatus. Balance and weights, electric-light bulb in which there is no air, Bunsen burner, blowpipe.

Procedure. Suspend the electric-light bulb from the hook on one pan of the balance. Put weights into the other pan until the bulb is counterpoised as perfectly as possible. Use the blowpipe and blow the flame of the Bunsen burner against the bulb until a hole is made in it. Is the bulb now perfectly counterpoised? Is it heavier or lighter than it was before?

Conclusion. Has air weight?

Part II

Aim. To ascertain whether air exerts pressure.

Apparatus. The same as in Part I.

Procedure. Observe the opening made in the bulb in Part I. Is the glass bent out or in around the opening? What force made the hole in the glass? Why was heat applied to it?

Conclusion. Does air exert pressure?

Part III

Aim. To ascertain in what directions air exerts pressure.

Apparatus. The same as in Parts I and II, with the addition of an air pump and a bell jar.

Procedure. Remove the bell jar to see that it is not fastened to the plate of the air pump. Place it again on the plate and

exhaust the air. Try to lift it again. What success do you have? Account for this. In which direction does this prove that the air presses? Observe the opening made in the bulb in Parts I and II. Was it made by pressure downward or from one side? Suppose the flame had been applied to the bottom of the suspended bulb. Would an opening have been made as before? If you are not sure, try it. Does air exert pressure upward?

Conclusion. In what directions does air exert pressure?

EXERCISE X

CONSTITUENTS OF THE ATMOSPHERE

Observe the color and odor of oxygen. Partially burn a match and blow it out, leaving the end glowing. Insert this into the bottle of oxygen. What occurs? Repeat the process to be sure that it is not an accident. Oxygen is sometimes called the *supporter of combustion.* Will air support combustion? Why will the fire in a stove burn better when the "draught" is open?

Attach a small quantity of steel wool to the end of a wire. Heat it red-hot in the flame of the Bunsen burner and insert it into the bottle of oxygen. What occurs? Will air support the combustion of steel? Compare air and oxygen as supporters of combustion. How do you account for the difference?

Attach a small candle to the top of a flat cork and float it on a vessel of water. Invert over it a tumbler with straight sides, keeping the mouth of the tumbler under water. What occurs? Account for this. When the tumbler was inverted it was full of gas (air). Is it now full of gas? Keep the water line inside and outside the tumbler at the same level and measure the length of that part now filled with gas. What proportion of the whole length of the tumbler is it? What proportion of the whole quantity has been used up? According to this, what proportion of the air is oxygen? According to the books, what proportion of the air is oxygen? What gas is found in the air in largest

quantity? If the proportion of this gas were not so large, what difference would there be in the rate of the burning of a building?

Cut a paraffin candle into pieces about half an inch long. Place three or four such pieces about six inches apart in the bottom of a V-shaped trough. Incline the trough at an angle of from 20 to 45 degrees with the horizontal. Invert a bottle of carbon dioxide above the upper end of the trough and remove the stopper. What results? Is carbon dioxide a supporter of combustion? Is it a heavy or a light gas? Describe the color and odor of this gas.

Summary. Name the three most important gases found in the atmosphere and give the proportion of each. Give color and odor of each. Of what use is each?

EXERCISE XI

COMBUSTION AND OXIDATION

Part I

Heat a small mass of steel wool red-hot, thus burning off all oil. Place it on a cork, moisten it thoroughly, and float the cork on water. Invert a wide-mouthed bottle over the floating cork and support it with its mouth just beneath the surface of the water. Note carefully the height of the water in the inverted bottle. Leave it in this position over night. In the morning again observe the height of the water within the bottle. Compare the amount of air now in the bottle with the amount there the day before. The part which disappeared was oxygen. Where do you suppose it went? What change do you notice in the appearance of the steel wool? The new substance which has appeared is called an *oxide of iron*. What can you see appropriate in this name? What is the common name for this particular oxide of iron? The process which you have observed is called *oxidation*. Define oxidation. Oxidation is sometimes called *slow combustion*. What can you see appropriate in this name?

What is the color of the oxide of iron which you have observed above? A very common color of oxide of iron is red. Examine and describe red ocher. Oxide of iron is the substance that nature has used to "paint the rocks red." Red and brown sandstone are usually colored with this material. Look for red, yellow, or rusty spots in blocks of sandstone or limestone. Bricks are usually red because the iron in the clay is oxidized in the process of burning.

Part II

What is the object of burning wood or other fuel in the stove? Does the combustion of steel wool (Exercise X) accomplish the same result? How do you know? What is the essential gas in this process?

In breathing, the oxygen is removed from the air in the lungs and is conveyed by the blood to all parts of the body. Here it unites with the various tissues. Characterize this oxidation of the tissues as rapid or slow combustion. Compare the result with the result of burning wood. What gas is essential in breathing? Why?

Did you ever notice that the temperature in a heap of decaying vegetable matter or about an old rotting log is different from the temperature of surrounding objects? If so, what difference did you notice? In what respects does decay resemble combustion?

EXERCISE XII

EVAPORATION AND CONDENSATION

Place a shallow vessel in one pan of the balances and partly fill it with water. Weigh it carefully and let it stand for several hours (or over night) in a place where there is a circulation of air. Weigh it again and compare with the first weight. Account for any change. The part which disappears is called *vapor* and the process is called *evaporation*. Is water vapor visible?

Put a drop of water on the table top. Set a watch crystal filled with ether in the water and cause a breeze to blow over it, by fanning or blowing, until the ether is evaporated. Lift the watch crystal. What change has occurred in the water? Has the water gained or lost heat? Has the watch crystal gained or lost heat? The ether in evaporating took up and carried away the heat.

Put a drop of alcohol in the palm of the hand. What sensation is felt? What becomes of the heat? Why do we wrap a wet cloth around a water jar? Is it desirable that the water in the cloth should evaporate? Where does the heat go in such a case? Where does it come from?

Fill a teakettle half full of water and cause it to boil vigorously. Does the water evaporate? Characterize this as rapid or slow evaporation. How may rapid evaporation be produced? Place some cold object just in front of the spout of the boiling kettle. What occurs? What effect did the presence of the cold object have on the temperature of the water vapor? What name is given to the process resulting from such a change of temperature? How did this affect the temperature of the cold object? Does condensation give heat to surrounding objects or take heat from them?

True water vapor is invisible. Do you find an area of true water vapor very near the end of the spout? What change has occurred to make it visible farther away from the spout? Why does this change occur? Which is capable of holding more water vapor, warm air or cold?

EXERCISE XIII

HUMIDITY

Humidity is the moisture in the atmosphere. When the atmosphere contains all the moisture that it possibly can, it is said to be *saturated*. Take the temperature and measure the dimensions of the laboratory. Refer to Table A and calculate the

capacity of this room for water vapor, that is, the amount of water vapor it is capable of holding at this temperature. Give the capacity in pounds. Does the room always have this amount of water vapor in it? The amount actually present, measured in grains per cubic foot, is called the *absolute humidity*.

Observe the wet and the dry bulb thermometers. Take the reading of the dry bulb thermometer and record it. This gives the temperature of the room. Read the wet bulb thermometer and record it. Compare this with the former reading. Why is there this difference? If the air is very dry, it will drink up the water from the wet bulb very rapidly. What effect will this have on the temperature recorded by the wet bulb thermometer? Will this increase or decrease the difference between the readings of the two thermometers? The ratio of the absolute humidity to the capacity is called the *relative humidity*. When the air is very dry, is the relative humidity great or small? When the difference between the readings of the wet and the dry bulb thermometers is great, is the relative humidity great or small? Refer to Table B and find the relative humidity in the laboratory. Tell how you found it. You have calculated the capacity of the laboratory, and now you know what per cent of this amount is actually present. From this calculate and record the weight of the water vapor now in the room. Give the weight in pounds.

Fill a brightly polished metal cup or can about half full of water at the temperature of the room. Gradually pour in ice water, stirring all the time, until a trace of moisture can be seen on the outside of the cup. Where does this moisture come from? Can you see it before it condenses? Compare the temperature of the can with that of the room. How must the can affect the temperature of the air in its immediate vicinity? Why does moisture condense on the surface of the can and not on other objects in the room? Carefully take and record the temperature of the water in the can. Allow the can to stand and become warmer until the moisture disappears. Take the temperature again and record it. Average these two

readings. The average is called the *dew-point* of the air at this particular time. The air immediately around the cup is at the dew-point. Is it at the dew-point elsewhere in the room? To what temperature must the air in the room fall before dew will gather on objects in the room?

When the air is at the dew-point, the relative humidity is 100 per cent. What does this mean? When the absolute humidity is great, is the dew-point reached at a high or a low temperature? Is dew-point always at the same temperature? Does the air always have the same amount of water vapor in it? Why does dew form on some nights and not on others?

Define humidity; capacity for water vapor; absolute humidity; relative humidity; dew-point.

TABLE A

GRAINS OF WATER VAPOR IN A CUBIC FOOT OF SATURATED AIR AT VARIOUS TEMPERATURES

DEG.	GRAINS	DEG.	GRAINS	DEG.	GRAINS	DEG.	GRAINS
10	.776	34	2.279	58	5.370	82	11.626
12	.856	36	2.457	60	5.745	84	12.356
14	.941	38	2.646	62	6.142	86	13.127
16	1.032	40	2.849	64	6.563	88	13.937
18	1.128	42	3.064	66	7.009	90	14.790
20	1.235	44	3.294	68	7.480	92	15.689
22	1.355	46	3.539	70	7.980	94	16.634
24	1.483	48	3.800	72	8.508	96	17.626
26	1.623	50	4.076	74	9.066	98	18.671
28	1.773	52	4.372	76	9.655	100	19.766
30	1.935	54	4.685	78	10.277	102	20.917
32	2.113	56	5.016	80	10.934	104	22.125

TABLE B, FOR FINDING RELATIVE HUMIDITY

Dry Bulb	Difference between Readings of the Dry and the Wet Bulb																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
0	68	35	3																	
2	71	41	12																	
4	73	46	19																	
6	75	50	25	1																
8	77	54	31	9																
10	79	57	36	15																
12	80	60	41	21	3															
14	82	63	45	29	10															
16	83	66	49	33	16															
18	84	68	53	38	22	7														
20	85	70	56	42	28	14														
22	86	72	59	45	32	19	7													
24	87	74	61	49	36	24	12													
26	88	75	64	52	40	29	18	7												
28	88	77	66	55	44	33	23	12	2											
30	89	78	68	57	47	37	27	17	8											
32	90	79	69	60	50	41	31	22	13	4										
34	90	81	72	62	53	44	35	27	18	9	1									
36	91	82	73	65	56	48	39	31	23	14	6									
38	91	83	75	67	59	51	43	35	27	19	12	4								
40	92	84	76	68	61	53	46	38	31	23	16	9	2							
42	92	85	77	70	62	55	48	41	34	28	21	14	7							
44	93	85	78	71	64	57	51	44	37	31	28	18	12	5						
46	93	86	79	72	65	59	53	46	40	34	28	22	16	10	4					
48	93	87	80	73	67	60	54	48	42	36	31	25	19	14	8	3				
50	93	87	81	74	68	62	56	50	44	39	33	28	22	17	12	7	2			
52	94	88	81	75	69	63	58	52	46	41	36	30	25	20	15	10	6			
54	94	88	82	76	70	65	59	54	48	43	38	33	28	23	18	14	9	5		
56	94	88	82	77	71	66	61	55	50	45	40	35	31	26	21	17	12	8	4	
58	94	89	83	77	72	67	62	57	52	47	42	38	33	28	24	20	15	11	7	3
60	94	89	84	77	73	68	63	58	53	49	44	40	35	31	27	22	18	14	10	6
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21	17	13	9
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23	20	16	12
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22	18	15
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24	21	17
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26	23	20
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28	25	22
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32	29	26
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34	31	28
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35	32	29
82	96	91	87	83	79	76	72	69	65	62	58	55	52	49	46	43	40	37	34	31
84	96	92	88	84	80	77	73	70	66	63	59	56	53	50	47	44	41	38	35	32
86	96	92	88	84	80	77	73	70	66	63	60	57	54	51	48	45	42	30	37	35
88	96	92	88	85	81	78	74	71	67	64	61	58	55	53	49	46	43	41	39	35
90	96	92	88	85	81	78	74	71	68	64	61	58	56	53	50	47	44	42	39	37
92	96	92	89	85	82	78	75	72	69	65	62	59	57	54	51	48	45	43	40	38
94	96	92	89	85	82	78	75	72	69	66	63	60	57	54	52	49	46	44	41	39
96	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	47	45	42	40
98	96	93	89	86	82	79	76	73	70	67	64	61	58	56	53	51	48	46	43	41
100	96	93	90	86	83	80	77	74	71	68	65	62	59	57	54	52	49	47	44	42

TABLE B (*continued*)

Dry Bulb	Difference between Readings of the Dry and the Wet Bulb																			
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
60	2																			
62	6	2																		
64	9	5	2																	
66	11	8	5	1																
68	14	11	8	4	1															
70	17	13	10	7	4	1														
72	19	16	13	10	7	4	1													
74	21	18	15	12	9	7	4	1												
76	23	20	17	14	12	9	6	4	1											
78	25	22	19	16	14	11	9	6	4	1										
80	27	24	21	18	16	13	11	8	6	4	1									
82	28	25	23	20	18	15	13	10	8	6	4	1								
84	30	27	25	22	20	17	15	12	10	8	6	4	2							
86	31	29	26	24	21	19	17	14	12	10	8	6	4	2						
88	33	30	28	25	23	21	18	16	14	12	10	8	6	4	2					
90	34	32	29	27	24	22	20	18	16	14	12	10	8	6	4	2				
92	35	34	30	28	26	24	22	19	17	15	13	11	9	8	6	4	2			
94	36	34	32	29	27	25	23	21	19	17	15	13	11	9	8	6	4	2	1	
96	37	35	33	31	29	26	24	22	20	18	17	15	13	11	9	7	6	4	3	1
98	39	36	34	32	30	28	26	24	22	20	18	16	14	13	11	9	7	6	4	3
100	40	37	35	33	31	29	27	25	23	21	19	18	16	14	12	11	9	7	6	4

EXERCISE XIV

LIGHT

Part I

Darken the laboratory, allowing only a single beam of sunlight to enter through a very small aperture made for the purpose. Fill with water a glass jar with straight sides, and add a little soap to make it cloudy. This will render visible the path of the beam. Use a mirror and direct the ray of light so that it will strike the surface of the water at any angle other than ninety degrees. Note and record any change in the direction of the path of the beam after it strikes the surface of the water. This change of direction is called *refraction*. Define refraction. Draw the apparatus and show the path of the beam of light, so

as to illustrate refraction. Give your drawing a title. When light enters any transparent substance obliquely from the air, this substance refracts the light.

Pass a beam of light through a triangular glass prism, and let the refracted light fall on a white wall or on a screen placed for the purpose. Describe what you see. How many colors can you see? Which color is refracted most? Which least? This band of colors is called the *spectrum*. Name in order the seven principal colors of the spectrum. Stand in such a position that your eye will be in the region of red light. What color can you see? Can you see any other colors from this position without moving the prism? What becomes of the colors which you do not see?

Raindrops refract and reflect the rays of the sun, thus forming the rainbow. How many colors does any one raindrop send forth? How many of these colors can you see from any one raindrop? What becomes of those which you do not see? When the sun is in the west, in which direction is the rainbow seen? What is the condition of the sky back of the rainbow? Name three conditions necessary for the formation of a rainbow. Compare the height of a rainbow which is seen just before sunset with the height of one which occurs earlier in the afternoon. Account for the difference. The portion of the rainbow which is visible forms an arc of a circle. What could be done to make the whole circle visible?

Part II

Cause a beam of sunlight to pass horizontally through the glass jar filled with soapy water. Look at the jar from the side at which the light enters. What color is it? Look at the jar from the side at which the light emerges. What color is it? What color of light passes through most readily? There is one color of the spectrum that passes readily through the upper regions of the atmosphere and goes out into space, suffering only slight change in its direction. What color do you think it is? Another (with those colors which are closely related to it)

is more interfered with, diffused, and reflected, until that is the only color which comes from the open sky to the earth. Which color is it? Why is the sky blue?

In the evening and early morning the light of the sun must come long distances through the earth's atmosphere. Why through greater distances than at noon? What colors of light are liable to "get tangled up" in the atmosphere before reaching us? Which one will come through most readily? Which of these will we see? What color would this make the sky appear to be in the evening and early in the morning? Does this accord with your experience?

EXERCISE XV

MAGNETISM

Thrust one end of a bar magnet into a box of tacks. Remove it and make a drawing of what you see. Place one end of the magnet near, but not touching, one end of the needle of a compass. What occurs? Repeat, presenting the magnet to the other end of the magnetic needle. Does it affect both ends of the needle alike? Tie a string to the middle of the magnet, suspend it, and let it come to rest. (Select a string that will not twist, or, instead of using the string, balance the magnet on two watch crystals, as in Fig. 2.) In which direction does it come to rest? Try repeatedly and compare results. The earth is a big magnet and acts upon your bar magnet very much as the magnet did upon the compass needle. Where are the magnetic poles of the earth? (Refer to the books, and give latitude and longitude.) Upon what property of the earth does the compass depend? When was the compass invented? To whom is it most valuable? How did the invention of the compass hasten the discovery of America?

FIG. 2. A Bar Magnet mounted on Two Watch Crystals so as to swing freely under the Influence of the Earth's Magnetism

Compare the direction of the magnetic needle with your north and south line (Exercise V). Does the needle point due north? If not, does it point east or west of due north? How many degrees? This difference measured in degrees east or west of due north is called *magnetic declination*. Refer to the map which shows magnetic declination in the United States. Determine and record the magnetic declination at the following points: Portland (Me.), Portland (Ore.), Los Angeles, Denver, St. Louis, Springfield (O.), Washington (D.C.), New York city. Name the states through which the line of no declination passes. Refer to the pilot chart of the North Atlantic ocean and trace the line of no declination (here called the line of no variation), naming islands near which it passes and telling where it strikes the coast of South America. Refer to the pilot chart of the North Pacific ocean and locate the line of no declination (variation). In what direction does the compass point at Manila, P.I.? What change would there be in the direction of the compass in sailing along the great circle route from Yokohama to San Francisco?

EXERCISE XVI

ISOTHERMS

Part I

The accompanying table gives temperatures as reported by the United States Weather Bureau at 8 A.M., Thursday, May 12, 1904. Use a fine-pointed pen and insert the proper figures as near as possible to each circle representing a town. Be very careful in selecting the proper circle for towns in the eastern part of the United States. Use your pencil and draw the isotherm of 40 degrees, beginning at Sault Ste. Marie, Mich. Draw the line toward the west, leaving north of the line all places having a temperature lower than 40 degrees, and south of the line all places having a temperature higher than 40 degrees. This line will be somewhat irregular. It will cross

into British Columbia. Begin with Tacoma, Wash., and draw the isotherm of 50 degrees. This line is very irregular in the eastern states. It passes through Pittsburg, Pa., to Asheville, N.C., where it makes a sharp curve, passing back toward the north through Wytheville, Va. Continue it through eastern Pennsylvania to the Atlantic ocean near New York city. Begin with Norfolk, Va., and draw the isotherm of 60 degrees. Begin with Jacksonville, Fla., and draw the isotherm of 70 degrees.

After your teacher approves your work, trace the isotherms in ink. Continue each at both ends about half an inch beyond the boundary of the country, and place large figures to indicate the temperature which is represented. Give your map an appropriate title.

Part II

Write a paper in which you answer the following questions about your map. In what region do the isotherms of 40, 50, and 60 degrees reach their farthest point north? Does this indicate that this region is warmer or colder than other regions in the same latitude? (Determine this by actual reading of temperatures.) There are two regions where these three isotherms make great bends toward the south. Does this indicate that these regions are warmer or colder than the other regions in the same latitude? (Determine this by actual reading of temperatures.) Give names to these regions. Characterize the lay of the land as *level*, *gently sloping*, *hilly*, *broken*, or *mountainous*. Compare the elevation of the two regions where the isotherms bend far south with the elevation of the lower Mississippi, Ohio, and Missouri valleys, where the isotherms bend far north. (See the map of the United States, which is shaded to show elevations.) What have the elevation and the lay of the land to do with the prevailing temperature of a region? Take an imaginary trip from west to east across the United States, along the parallel of 40 degrees north latitude. Tell between what degrees

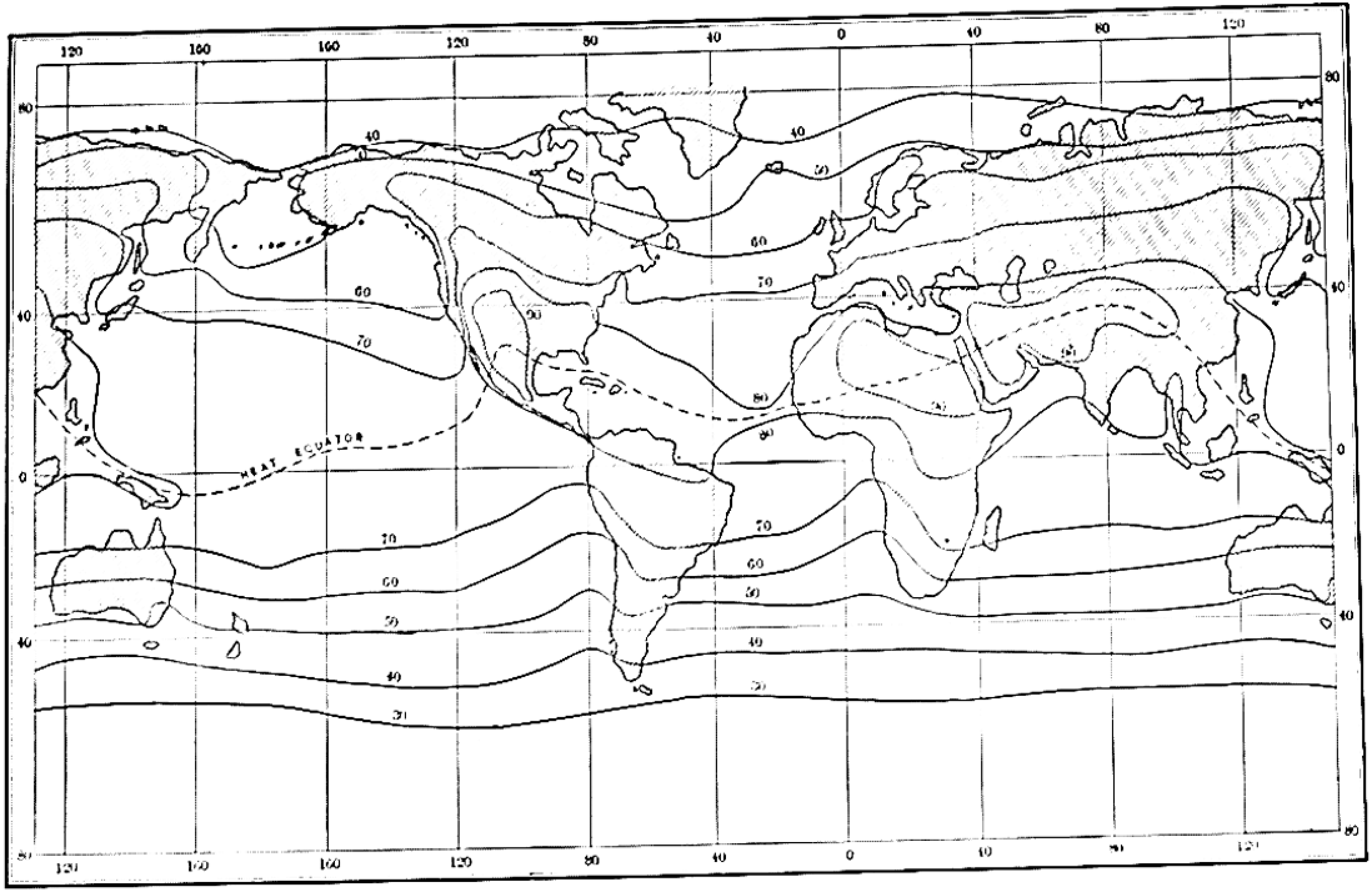

Fig. 3. Isothermal Lines showing the Mean Temperature of the World for July

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of longitude or in what states you are passing from a warmer to a colder region, according to this map; also from a colder to a warmer region.

Part III

It should be borne in mind that the map which you have constructed and used shows the conditions of temperature as they existed on one day only at a particular time of this day. Figs. 3 and 4 are isothermal maps made by averaging temperatures for an entire month during a period of several years. In what respects are these maps superior to yours?

Refer to Fig. 3, which shows the isotherms for the month of July. In passing from the sea to the land in the northern hemisphere do the isotherms bend toward the north or toward the south? (Notice the marked deflection on the west coast of North America.) Does this indicate that the land is warmer or cooler than the sea? Account for the difference in temperature.

Refer to Fig. 4, which shows the isotherms for the month of January. In passing from the sea to the land in the northern hemisphere do the isotherms bend toward the north or toward the south? (Again notice the marked deflection on the west coast of North America.) Does this indicate that the land is warmer or cooler than the sea? Account for the difference in temperature.

In what part of the world do you find the highest temperature in July? Is this on the land or on the sea? In what part of the world do you find the lowest temperature in January? Is this on the sea or on the land?

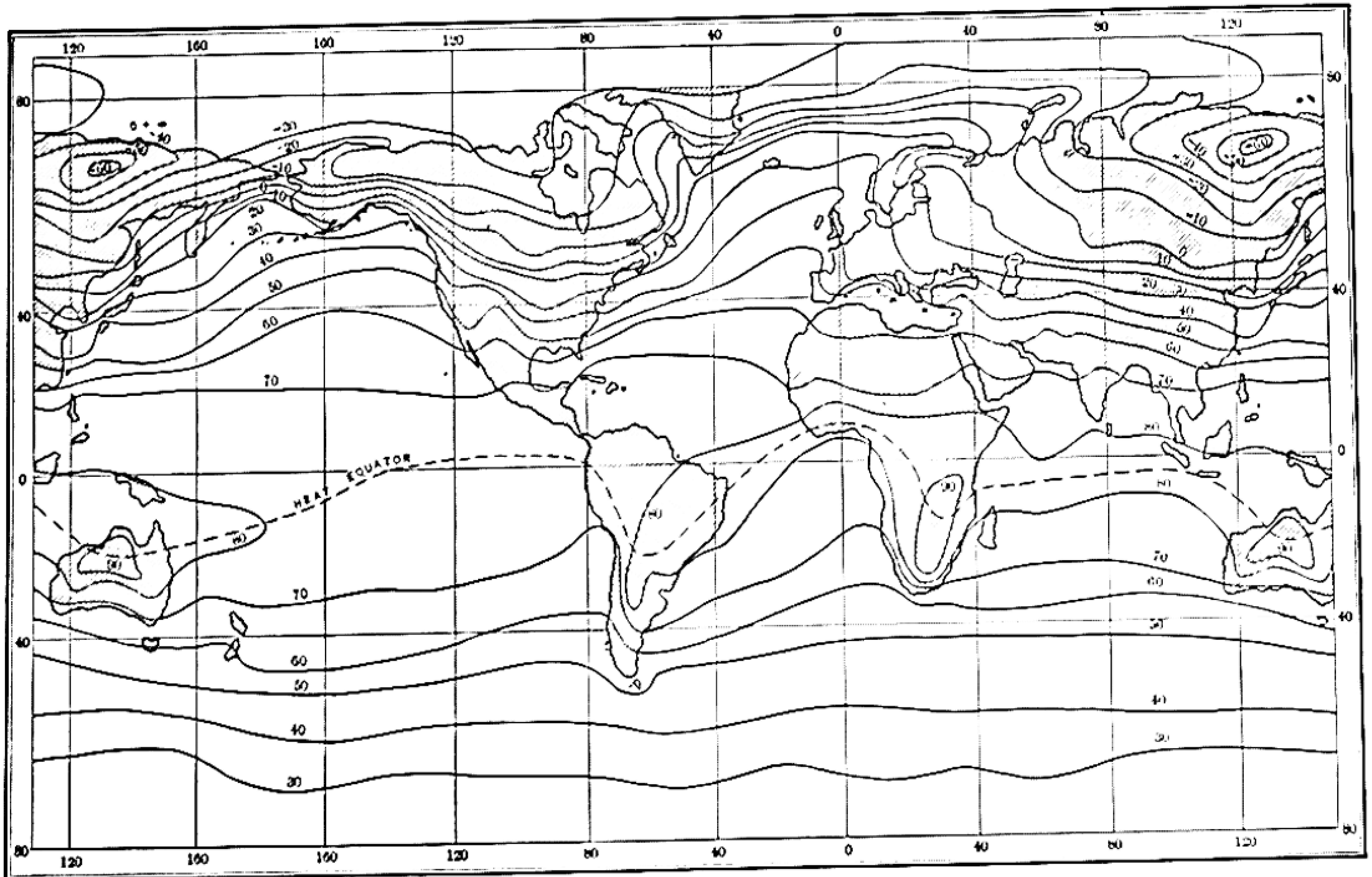

Fig. 4. Isothermal Lines showing the Mean Temperature of the World for January

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TEMPERATURES AT VARIOUS PLACES IN THE UNITED STATES

At 8 a.m., Thursday, May 12, 1904

Albany, N.Y.	48
New York, N.Y.	48
Scranton, Pa.	44
Harrisburg, Pa.	52
Philadelphia, Pa.	52
Atlantic City, N.J.	52
Baltimore, Md.	54
Washington, D.C.	54
Mount Weather, Va.	50
Lynchburg, Va.	54
Richmond, Va.	50
Norfolk, Va.	60
Wytheville, Va.	50
Charlotte, N.C.	58
Asheville, N.C.	50
Raleigh, N.C.	60
Hatteras, N.C.	64
Wilmington, N.C.	64
Charleston, S.C.	66
Augusta, Ga.	60
Savannah, Ga.	64
Jacksonville, Fla.	70
Jupiter, Fla.	76
Key West, Fla.	78
Atlanta, Ga.	62
Macon, Ga.	62
Tampa, Fla.	70
Pensacola, Fla.	70
Mobile, Ala.	62
Montgomery, Ala.	66
Birmingham, Ala.	64
Meridian, Miss.	62
Vicksburg, Miss.	62
New Orleans, La.	66
Shreveport, La.	62
Little Rock, Ark.	62
Palestine, Tex.	62
Galveston, Tex.	72
San Antonio, Tex.	64
Corpus Christi, Tex.	72
Memphis, Tenn.	64
Nashville, Tenn.	56
Chattanooga, Tenn.	56
Knoxville, Tenn.	56
Louisville, Ky.	62
Lexington, Ky.	60
Indianapolis, Ind.	60
Cincinnati, Ohio	56
Columbus, Ohio	54
Elkins, W.Va.	42
Parkersburg, W.Va.	52
Pittsburg, Pa.	50
Parry Sound, Ont.	38
Saugeen, Ont.	50
Syracuse, N.Y.	44
Oswego, N.Y.	44
Rochester, N.Y.	48
Buffalo, N.Y.	48
Erie, Pa.	52
Cleveland, Ohio	52
Toledo, Ohio	58
Detroit, Mich.	56
Alpena, Mich.	44
Sault Ste. Marie, Mich.	40
Houghton, Mich.	38
Marquette, Mich.	38
Escanaba, Mich.	42
Green Bay, Wis.	54
Grand Rapids, Mich.	62
Chicago, Ill.	62
Duluth, Minn.	34
St. Paul, Minn.	44
La Crosse, Wis.	48
Dubuque, Iowa	58
Davenport, Iowa	62
Des Moines, Iowa	50
Keokuk, Iowa	66
Springfield, Ill.	64
St. Louis, Mo.	64
Cairo, Ill.	62
Kansas City, Mo.	62
Wichita, Kans.	62
Concordia, Kans.	56
Omaha, Neb.	50
Valentine, Neb.	42
Sioux City, Iowa	44
Huron, S.D.	42
Pierre, S.D.	46
Moorhead, Minn.	38
Bismarck, N.D.	34
Williston, N.D.	34
Havre, Mont.	36
Helena, Mont.	36
Miles City, Mont.	36
Kalispell, Mont.	34
Pocatello, Ida.	38
Boisé, Ida.	44
Rapid City, S.D.	42
Lander, Wyo.	38
Salt Lake City, Utah.	44
Cheyenne, Wyo.	33
North Platte, Neb.	44
Denver, Col.	40
Amarillo, Tex.	56
Pueblo, Col.	44
Dodge, Kans.	60
Oklahoma, Okla.	62
Abilene, Tex.	62
El Paso, Tex.	60
Santa Fé, N.M.	42
Flagstaff, Ariz.	42
Yuma, Ariz.	62
Phœnix, Ariz.	62
Victoria, B.C.	54
Kamloops, B.C.	36
Spokane, Wash.	42
Tacoma, Wash.	50
Portland, Ore.	64
Roseburg, Ore.	48
Baker City, Ore.	36
Carson City, Nev.	44
Eureka, Cal.	50
Red Bluff, Cal.	62
San Francisco, Cal.	52
Los Angeles, Cal.	52
San Diego, Cal.	56

EXERCISE XVII

THE BAROMETER

Aim. To ascertain whether the pressure of the atmosphere can be measured.

Apparatus. Two glass tubes, each closed at one end, one 18 inches long and one 32 inches long; a cup and mercury.

Procedure. Fill the 18-inch tube and invert it in the cup of mercury. What happens? Account for this. Fill the 32-inch tube with mercury and invert it in the cup of mercury. What happens? Account for this. If the pressure of the air could be increased, how would the length of the column of mercury be affected? If the pressure of the air were decreased, how would the length of the column of mercury be affected? What do you know of air pressure at high altitudes? How would the mercury column stand at high altitudes? How high is the average mercury column at sea level? Make a drawing showing the 32-inch tube inverted in the cup of mercury.

Conclusion. Can atmospheric pressure be measured? What name is given to the instrument used for this purpose?

EXERCISE XVIII

ISOBARS

The accompanying table gives barometric pressure in inches and hundredths at various places in the United States, at 8 A.M., Wednesday, March 2, 1904. Use a fine-pointed pen and put the figures on the map in the proper places. Place the figures so that the circle which represents a town shall come in the place of the decimal point. Find the place having the lowest barometric reading and write there the word LOW. Does this mean that the atmospheric pressure at this place is great or small? Draw isobars as follows: 29.60, beginning at Omaha, Neb.; 29.80, beginning at Springfield, Mo.; 30.00, beginning at Los Angeles, Cal. Draw also isobars of 30.10, 30.20, and 30.30.

These will extend through parts of the Atlantic and Middle states. They will also extend through parts of California, Oregon, and Washington. Do not draw isobars at any place in Canada or Mexico unless there are figures to show that they should be so drawn. Finish the map by placing large figures to show pressure at the ends of isobars or at some conspicuous place on the isobars. Give your map a title.

BAROMETRIC PRESSURE IN INCHES AND HUNDREDTHS

At 8 A.M., Wednesday, March 2, 1904

Binghamton, N.Y.	30.32	Birmingham, Ala.	30.08
Albany, N.Y.	30.28	Meridian, Miss.	30.08
New York, N.Y.	30.30	Vicksburg, Miss.	30.02
Scranton, Pa.	30.22	New Orleans, La.	30.12
Harrisburg, Pa.	30.28	Shreveport, La.	29.96
Philadelphia, Pa.	30.32	Fort Smith, Ark.	29.82
Atlantic City, N.J.	30.36	Little Rock, Ark.	29.94
Baltimore, Md.	30.30	Palestine, Tex.	29.96
Washington, D.C.	30.32	Galveston, Tex.	30.06
Lynchburg, Va.	30.26	Taylor, Tex.	29.92
Richmond, Va.	30.30	San Antonio, Tex.	29.94
Norfolk, Va.	30.30	Corpus Christi, Tex.	29.98
Wytheville, Va.	30.20	Memphis, Tenn.	29.98
Charlotte, N.C.	30.20	Nashville, Tenn.	30.06
Asheville, N.C.	30.14	Knoxville, Tenn.	30.10
Raleigh, N.C.	30.24	Lexington, Ky.	30.08
Hatteras, N.C.	30.22	Evansville, Ind.	29.98
Wilmington, N.C.	30.20	Indianapolis, Ind.	30.00
Charleston, S.C.	30.16	Cincinnati, Ohio	30.08
Augusta, Ga.	30.14	Columbus, Ohio	30.10
Savannah, Ga.	30.14	Parkersburg, W.Va.	30.14
Jacksonville, Fla.	30.16	Pittsburg, Pa.	30.14
Jupiter, Fla.	30.18	White River, Ont.	30.02
Key West, Fla.	30.14	Port Arthur, Ont.	30.08
Atlanta, Ga.	30.10	Parry Sound, Ont.	30.08
Macon, Ga.	30.12	Saugeen, Ont.	30.08
Tampa, Fla.	30.18	Syracuse, N.Y.	30.20
Pensacola, Fla.	30.16	Oswego, N.Y.	30.18
Mobile, Ala.	30.14	Rochester, N.Y.	30.14
Montgomery, Ala.	30.10	Buffalo, N.Y.	30.14

Erie, Pa.	30.14	Kalispell, Mont.	30.04
Cleveland, Ohio	30.12	Lewiston, Ida.	30.16
Toledo, Ohio	30.10	Pocatello, Ida.	29.86
Detroit, Mich.	30.10	Boisé, Ida.	30.14
Alpena, Mich.	30.04	Rapid City, S.D.	29.74
Sault Ste. Marie, Mich.	30.00	Lander, Wyo.	29.46
Houghton, Mich.	30.02	Salt Lake City, Utah	29.70
Marquette, Mich.	30.02	Modena, Utah	29.92
Escanaba, Mich.	29.94	Grand Junction, Col.	29.80
Green Bay, Wis.	29.90	Cheyenne, Wyo.	29.50
Grand Rapids, Mich.	30.00	North Platte, Neb.	29.56
Milwaukee, Wis.	29.90	Denver, Col.	29.46
Chicago, Ill.	29.94	Amarillo, Tex.	29.72
Duluth, Minn.	29.94	Pueblo, Col.	29.56
St. Paul, Minn.	29.70	Dodge, Kans.	29.68
La Crosse, Wis.	29.76	Oklahoma, Okla.	29.66
Dubuque, Iowa	29.76	Fort Worth, Tex.	29.86
Davenport, Iowa	29.78	Abilene, Tex.	29.80
Des Moines, Iowa	29.68	El Paso, Tex.	29.90
Keokuk, Iowa	29.86	Santa Fé, N.M.	29.92
Springfield, Ill.	29.86	Flagstaff, Ariz.	30.02
St. Louis, Mo.	29.88	Yuma, Ariz.	29.94
Cairo, Ill.	29.96	Phœnix, Ariz.	29.96
Springfield, Mo.	29.80	Victoria, B.C.	30.30
Kansas City, Mo.	29.74	Kamloops, B.C.	30.28
Wichita, Kans.	29.66	Spokane, Wash.	30.18
Concordia, Kans.	29.64	Walla Walla, Wash.	30.28
Omaha, Neb.	29.60	Tacoma, Wash.	30.32
Valentine, Neb.	29.40	Portland, Ore.	30.32
Sioux City, Iowa	29.54	Roseburg, Ore.	30.26
Huron, S.D.	29.52	Baker City, Ore.	30.22
Moorhead, Minn.	29.88	Carson City, Nev.	29.82
Bismarck, N.D.	30.00	Winnemucca, Nev.	29.88
Williston, N.D.	30.06	Red Bluff, Cal.	30.08
Battleford, Sask.	30.30	San Francisco, Cal.	30.12
Havre, Mont.	30.26	Fresno, Cal.	30.12
Helena, Mont.	30.08	Los Angeles, Cal.	30.00
Yellowstone Park, Wyo.	29.68	San Diego, Cal.	29.96
Miles City, Mont.	30.16		

EXERCISE XIX

OBSERVATIONS OF THE WEATHER

Make observations, read the instruments, refer to the weather map, and fill a table similar to the accompanying table. Make this record each day for one month.

In filling column 2, let ○ represent a clear sky, ● cloudy, ◑ one half of the sky overcast, etc.

In columns 8 and 19 indicate wind direction by arrows. A change may be indicated by a curve or by a sharp turn.

In column 20 use the following abbreviations: C, calm; L, light, just moving the leaves of trees, or blowing the smoke slowly away from smokestacks; M, moderate, moving small branches; B, brisk, swaying branches, blowing up dust; H, high, blowing up twigs from the ground, swaying whole trees; G, gale, breaking small branches, blowing down shade trees, etc.

In column 22 give quadrant, or, if we are very near the center of the area of low pressure, write *low*.

In column 23 name the state in which the area is central.

In column 25 give miles per day.

In column 26 name the region of the United States, as "Lake region," "eastern Gulf states," etc.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Date	Clear or cloudy	Kind of clouds	Kind of precipitation	Amount of precipitation	Rainstorm, windstorm, or other storm	Time of storm	Wind direction during storm	Barometer (—— A.M.)	Barometer (noon)	Barometer (—— P.M.)	Thermometer (—— A.M.)	Thermometer (noon)	Thermometer (—— P.M.)	Wet bulb (——)	Relative humidity	Maximum thermometer	Minimum thermometer	Wind direction during the day	Wind velocity	Dew, fog, frost	Our position in cyclone	Location of areas of low pressure	Direction of movement since yesterday	Velocity of different cyclones	Areas of rainfall in the United States

EXERCISE XX

PREVAILING WINDS

Observe the pilot chart of the North Atlantic ocean. How is wind direction indicated? (See explanation near the lower left-hand corner of the chart.) How is the percentage of calm days in any region indicated?

From what direction are the prevailing winds from 10 to 20 degrees north latitude? What name is given to these winds? (See the name printed in blue at both the northern and the southern limits of these winds.) From what direction are the prevailing winds from the equator to the parallel of 5 degrees north latitude, during the summer months? What name is given to these winds? Compare the percentage of calm days in the region where these two winds meet with the number in the region from 10 to 20 degrees north latitude. What name is given to this region of calms? (See the text-books.) At what time of the year is this region of calms farthest north? farthest south? Where does the north limit of northeast trades strike the United States in December? in March? in September?

Trace with a pointer an irregular line from the Bermudas (65 degrees west, 32 degrees north) to the Azores (28 degrees west, 38 degrees north), passing through the points having the highest percentage of calm days. Give the date of the map used in tracing this line. Describe the general direction of this line from the former point to the latter. Compare with the line of the northern limit of northeast trades. What name is given to this region of calms? From what direction are the prevailing winds from 15 to 20 degrees north of this region of calms? How far north could you go, according to this map, and still find the same winds?

Why is there a difference between the route of sailing vessels bound from New York to the equator and sailing vessels bound from the equator to New York?

Observe the chart for the North Pacific. What kind of a line is that portion of the sailing route which is represented from

San Francisco to Australia? from Australia to San Francisco by way of the western passage? Why is there this difference? Why do sailing vessels from San Diego to the strait of Juan de Fuca put out to sea so far before turning north? Give latitude of northeast trades in the Pacific ocean from June to September; from December to March. Account for the difference.

EXERCISE XXI

WINDS IN A CYCLONE

Draw a rectangle six inches long and an inch and a half wide. Divide this into four squares and write the word Low in the center of each.

Observe the United States weather maps. The arrows indicate the direction of the wind. Observe the map for March 5, 1904. What is the direction of the wind in the northeast quadrant? Observe the arrows nearest the center of the area of low barometer. What is the direction of the wind in the northwest quadrant? in the southwest quadrant? in the southeast quadrant? In the first of your squares put at least four arrows to show the direction of the wind about the area of low barometer. Under this square write the date. Observe the weather maps for the following dates and fill in the other squares as you did the first one: March 7, 1904; March 19, 1904; March 30, 1904. Give your completed work the title: "Direction of the winds about areas of low pressure, taken from the United States Weather Map."

Answer the following questions. What is the shape of the path of the winds near an area of low pressure? Do the winds in their movements seem to be approaching the center of the area of low pressure or constantly getting farther away? Does this indicate that the column of air at the center is ascending or descending? Why does this column of air move in this way?

Draw four more squares and put the word High in the center of each. Observe the weather maps for the following dates and

place arrows to indicate the directions of the wind: March 4, 1904; March 5, 1904; March 7, 1904; March 29, 1904. What is the shape of the path of the winds near an area of high pressure? Do the winds in their movements seem to be approaching the center of the area of high pressure or constantly getting farther away? Does this indicate that the column of air is ascending or descending? Why does this column of air move in this way?

Characterize the movement of the winds about an area of low pressure as *clockwise* or *counter-clockwise*. Account for the direction of this movement. What name do the books give to such a movement of the winds? Refer to any one of the maps on which a distinct low barometer is indicated, and measure the distance in miles across the region whose winds are influenced by the low pressure, that is, the region in which the majority of the arrows indicate that the wind is blowing in the general direction given above. Tell the date of the map from which you take your measurements. Characterize the movement of the winds about an area of high pressure as clockwise or counterclockwise. Account for the direction of this movement. What name do the books give to such a movement of the winds?

EXERCISE XXII

AREAS OF PRECIPITATION

When a mass of air rises, does the pressure upon it increase or decrease? Why? What change of volume does this produce? What change of temperature? What effect will this have on its capacity for water vapor? If it was nearly saturated when it began to rise, what will probably result from its rising? In which do you think you would find greater rainfall, a cyclone or an anticyclone?

Refer to the weather maps of the following dates: March 7, 11, 16, 19, 29, 31, in the year 1904. Record the number of cases in which the region of precipitation coincides with the

area of low pressure. Record the number in which it does not coincide, but is nearer the area of low pressure than it is to the area of high pressure. Record the number in which the region of rainfall is nearer the area of high pressure than it is to the area of low pressure. Do these observations justify your answers in the preceding paragraph?

EXERCISE XXIII

TEMPERATURES IN CYCLONES AND ANTICYCLONES

Examine the weather map for Thursday, March 3, 1904. What is the temperature represented by the isotherm passing nearest the center of the area of low pressure? by the isotherm passing nearest the center of the area of high pressure?

Which has the higher temperature, the area of high pressure or the area of low pressure? What reason can you assign for this? What has been the change of temperature during the last twenty-four hours near the area of low pressure? (Note the more or less circular area inclosed by the line of red dots. Read words and figures in red, and record the number of degrees colder or degrees warmer.) What has been the change of temperature near the area of high pressure during the same time?

Examine maps for March 2, 3, 4, 11, 16, 19, in the year 1904, and tabulate the results of your observations according to the accompanying form:

Date	Temperature		Which is Warmer, Low or High?	Change of Temperature in the last 24 Hours	
	At low	At high		Near low	Near high

EXERCISE XXIV

MOVEMENTS OF LOW BAROMETER IN THE UNITED STATES

You have drawn the isobars for Wednesday, March 2, 1904 (Exercise XVIII). At what point was the center of the area of low pressure for that day? Where is the center of the area of low pressure on the map for March 3? In what direction is it from that of March 2? The long line of arrows on the map of March 3 traces the path of this storm center. At Valentine, Neb., a small figure 2 placed above the circle indicates that the storm was central there on the second day of the nonth, and the letters A.M. just below the circle indicate that it was present in the forenoon of that day. Where was the storm center in the afternoon of that day? Where was this storm first observed? (Note the first of the small figures.) On what day was it first observed? At what time of day? Can you find any traces of this storm on the map for March 4? If so, where?

How many miles did the storm move from the morning of March 1 to the morning of March 2? How far did it move from March 2 to March 3? How far from March 3 to March 4? What is the average rate in miles per day? Find the average rate in miles per day for the storm marked on the map of March 11. Do the same for the maps of March 16 and 19. Find the average rate in miles per day for these four storms. Near what point do the majority of these storms first reach the United States? In what direction do they move across the United States? Refer to the pilot charts of the North Atlantic ocean and observe the average path taken by storms after they leave the United States. Refer to the pilot charts of the North Pacific ocean and determine the average path of storms across the Pacific ocean before they reach the United States.

Use the blank weather map and trace the paths of storms for March 3, 11, 16, and 19, in the year 1904. Mark the dates of each storm track as they are marked on the weather map. Give your map a title. The following title is suggested: "Map of

the paths of low barometer across the United States, taken from United States weather maps for March 3, 11, 16, and 19, in the year 1904."

EXERCISE XXV

WEATHER FORECASTING

Suppose an area of low pressure is approaching your home from the southwest. From which direction is the wind blowing at your home? Is the barometer rising or falling? What change in temperature will probably occur? What change in condition of cloudiness? Suppose an area of low pressure is receding toward the northeast. From which direction is the wind blowing at your home? Is the barometer rising or falling? What change in temperature will probably occur? What change in condition of cloudiness?

Suppose that on Monday at your home the wind is blowing from the southeast and the barometer is falling. In which direction from you is the area of low pressure? Suppose that on Tuesday the wind is blowing from the south and the barometer is low. In which direction from you is the center of the storm? Suppose that on Wednesday the wind is blowing from the west, the barometer is high, and the temperature is low. In which direction from you is the area of low pressure? Read the paragraph printed in red on the Washington weather map. Copy that portion which applies to the conditions supposed above for Monday, Tuesday, and Wednesday, and tell the source of the quotation.

Observe the local weather map without reading the forecast. Using all that you have learned on the subject, make a forecast for your locality for the next twenty-four hours. Compare this with the Weather Bureau predictions and record the difference, if any. After twenty-four hours compare both forecasts with the actual conditions of the weather and record results.

EXERCISE XXVI

RAINFALL

Part I

The accompanying table gives the average annual rainfall in inches for a period of twenty years at various places in the United States. Use the outline map of the United States and place the figures, in ink, as near as possible to the circles representing the proper towns. Draw *isohyetals* (lines connecting points having equal annual rainfall) of 10, 20, 30, 40, 50, and 100 inches. Shade with blue the various belts, making the intensity of shading somewhat proportional to the depth of rainfall represented. Thus the regions of great rainfall will be dark blue, and the regions of least rainfall will be left unshaded.

Part II

Write a paper in which you answer the following questions. In what part of the United States do you find the heaviest rainfall? Why is the rainfall so heavy in this region? (See Exercises XX and XXIV.) Why is the rainfall not so great in western Nebraska?

Refer to Fig. 5. Compare the rainfall of Chile with that of Argentina. What winds prevail in these countries? What has this to do with the difference in rainfall? What has the lay of the land to do with the difference in rainfall? What parts of the world have the heaviest rainfall? Compare the amount of rainfall along the equator with that about the tropics.

What is the movement of the winds in equatorial regions? (See Exercise XX.) What has this to do with excessive rainfall? Characterize the rainfall as great or small in the regions of northeast and southeast trades. Is the capacity for water vapor increasing or decreasing in the region of the trade winds? Explain.

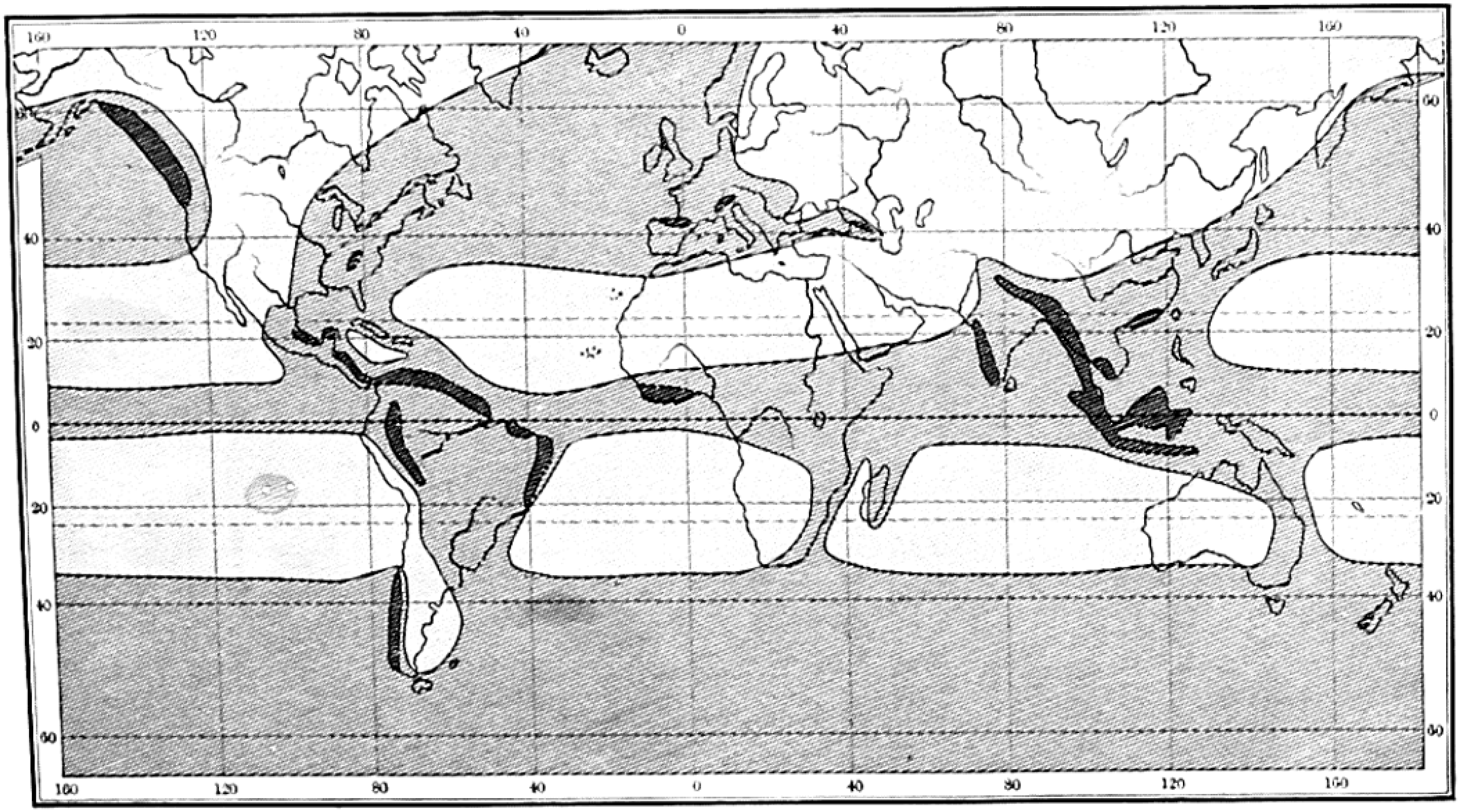

Fig. 5. Average Annual Rainfall of the World

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AVERAGE ANNUAL RAINFALL IN THE UNITED STATES

Father Point, Que.	33	Louisville, Ky.	45	Helena, Mont.	15
Eastport, Me.	44	Indianapolis, Ind.	42	Miles City, Mont.	13
Northfield, Vt.	34	Cincinnati, Ohio	41	Lewiston, Ida.	17
Portland, Me.	43	Columbus, Ohio	38	Pocatello, Ida.	13
Concord, N.H.	40	Parkersburg, W.Va.	43	Boisé, Ida.	14
Boston, Mass.	45	Pittsburg, Pa.	36	Rapid City, S.D.	16
Providence, R.I.	46	White River, Ont.	25	Lander, Wyo.	13
Albany, N.Y.	39	Port Arthur, Ont.	25	Salt Lake City, Utah	17
New York, N.Y.	45	Parry Sound, Ont.	38	Modena, Utah	7
Harrisburg, Pa.	42	Saugeen, Ont.	34	Grand Junction, Col.	8
Philadelphia, Pa.	42	Oswego, N.Y.	37	Durango, Col.	17
Washington, D.C.	44	Buffalo, N.Y.	38	Cheyenne, Wyo.	13
Richmond, Va.	44	Cleveland, Ohio	36	North Platte, Neb.	18
Norfolk, Va.	50	Detroit, Mich.	32	Denver, Col.	14
Wytheville, Va.	42	Alpena, Mich.	34	Amarillo, Tex.	22
Charlotte, N.C.	50	Sault Ste. Marie, Mich.	36	Pueblo, Col.	12
Raleigh, N.C.	49	Marquette, Mich.	32	Dodge, Kans.	21
Hatteras, N.C.	63	Green Bay, Wis.	31	Fort Worth, Tex.	34
Wilmington, N.C.	52	Milwaukee, Wis.	31	Abilene, Tex.	24
Charleston, S.C.	49	Chicago, Ill.	34	Roswell, N.M.	18
Augusta, Ga.	48	Duluth, Minn.	30	Santa Fé, N.M.	15
Savannah, Ga.	50	St. Paul, Minn.	29	Flagstaff, Ariz.	24
Jacksonville, Fla.	53	La Crosse, Wis.	31	Yuma, Ariz.	3
Jupiter, Fla.	60	Charles City, Iowa	29	Phœnix, Ariz.	7
Key West, Fla.	38	Dubuque, Iowa	34	Victoria, B.C.	38
Atlanta, Ga.	52	Davenport, Iowa	33	Neah Bay, Wash.	112
Tampa, Fla.	53	Des Moines, Iowa	32	Spokane, Wash.	18
Pensacola, Fla.	58	Keokuk, Iowa	35	Walla Walla, Wash.	17
Mobile, Ala.	63	Springfield, Ill.	38	Tacoma, Wash.	52
Montgomery, Ala.	52	St. Louis, Mo.	41	Portland, Ore.	45
Meridian, Miss.	58	Cairo, Ill.	42	Glenora, Ore.	136
Vicksburg, Miss.	53	Springfield, Mo.	44	Roseburg, Ore.	35
New Orleans, La.	56	Kansas City, Mo.	36	Baker City, Ore.	20
Shreveport, La.	47	Wichita, Kans.	30	Carson City, Nev.	12
Fort Smith, Ark.	41	Omaha, Neb.	30	Winnemucca, Nev.	9
Little Rock, Ark.	51	Valentine, Neb.	20	Eureka, Cal.	45
Palestine, Tex.	44	Sioux City, Iowa	25	Red Bluff, Cal.	24
Galveston, Tex.	48	Huron, S.D.	21	Sacramento, Cal.	20
San Antonio, Tex.	28	Pierre, S.D.	17	San Francisco, Cal.	23
Corpus Christi, Tex.	26	Moorhead, Minn.	24	Fresno, Cal.	9
Memphis, Tenn.	51	Bismarck, N.D.	18	Independence, Cal.	6
Nashville, Tenn.	49	Williston, N.D.	14	San Luis Obispo, Cal.	21
Chattanooga, Tenn.	53	Battleford, Sask.	14	Los Angeles, Cal.	16
Knoxville, Tenn.	50	Havre, Mont.	14	San Diego, Cal.	9

EXERCISE XXVII

ZONES OF CLIMATE

Part I

What is meant by the heat equator? Where does it reach its farthest point north in July? (Refer to Fig. 3.) Where does it reach its farthest point south in July? About what is its average latitude for this month? Where does it reach its farthest point south in January? (Refer to Fig. 4.) Where does it reach its farthest point north in January? About what is its average latitude for this month? Is the heat equator farther from the geographical equator in July or in January? Account for the difference.

Professor Davis says: "At the head of the Gulf of Guinea, west equatorial Africa, rain is most abundant in March and from October to November. In Ceylon the rainfall is greater in May and October than in any other months; at the city of Quito, Ecuador, in April and November." How do you explain these double rainy seasons?

Part II

What is meant by range of temperature? Refer to Fig. 6 and answer the following questions.

What point on the earth has the greatest range of temperature? What point ranks next? Are these points on sea or land? Are they densely or sparsely populated? What places have least range of temperature? Do any densely populated countries lie within this belt? Which is more desirable for residence, other things being equal, great or small range of temperature? How does climate help to make men industrious?

What are the points of greatest range of temperature in the southern hemisphere? Compare these ranges with those of the northern hemisphere and account for the difference. If the earth's

surface were all land, where would be the points of greatest range of temperature? Why are the points of greatest range in the northern hemisphere not located farther north?

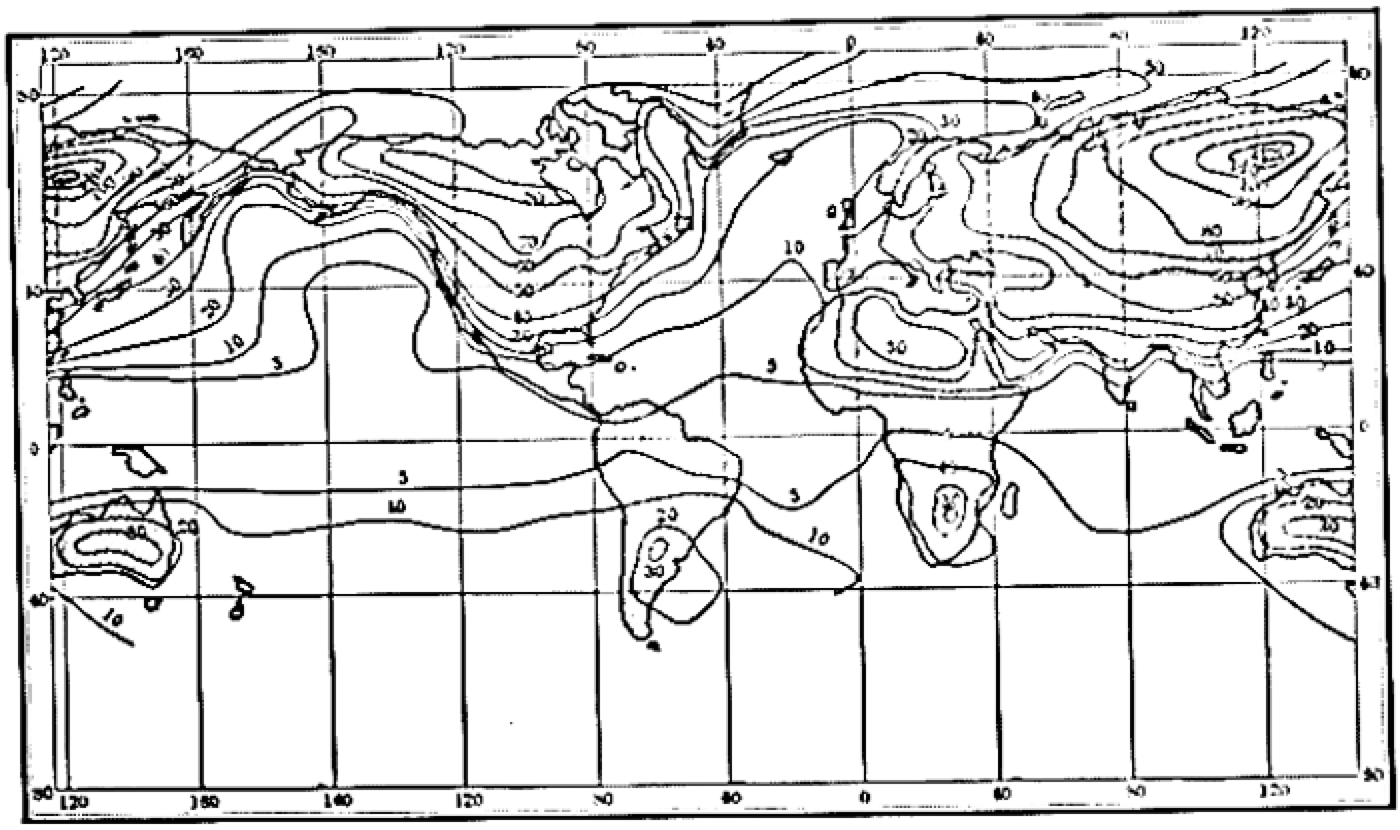

Fig. 6. Lines of Equal Annual Range of Temperature

Part III

Compare the east and the west coasts of the United States in range of temperature (e.g. San Francisco, Cal., and Norfolk, Va.; or Portland, Ore., and Eastport, Me.). How do you account for the difference? (See Exercise XX.) Make similar comparison of the east and the west coasts of Eurasia (e.g. Norway and Kamchatka). Compare the east coast of North America and the west coast of Eurasia (e.g. Labrador and England).

Part IV

Where is the belt of tropical calms in the northern hemisphere? (See Exercise XX.) Is this a region of high or low barometric pressure? (See the small maps on the pilot charts.) Are conditions here favorable for large rainfall? (See Exercise XXII.) Why? How is this region of calms related to the arid regions of the southwestern United States? In what countries

of the eastern hemisphere do you find extensive deserts? In what latitude are they? Compare this with the latitude of the region of calms. Do you find deserts in the southern hemisphere corresponding to the region of tropical calms?

Southern California is alternately in the belt of tropical calms and the region of prevailing westerlies. During what time of year is it in the belt of calms? What kind of weather would you expect in this region at this time?

Give all the reasons that you can for the marked difference between the rainfall on the coast of southern California and that on the coast of Oregon.

EXERCISE XXVIII

ELEVATIONS AND DEPRESSIONS OF THE EARTH'S SURFACE DRAWN TO SCALE

Refer to the map of the United States showing elevations by colors (Fig. 7). Use cross-section paper and draw a profile along the parallel of 37 degrees north latitude. Use a horizontal scale of 2 millimeters to 1 degree, vertical scale of 2 millimeters to 1000 feet. Draw a rectangle around your profile, marking the degrees above and the elevations on the right and left. Indicate longitude as either *east* or *west*. Below the rectangle write the names of the principal land and water features, such as *Pacific Ocean*, *Coast Range*, *Valley of California*, *Sierra Nevada Mountains*, *Great Basin*, etc. Number these features consecutively and place corresponding figures beneath the proper part of the profile. Give your profile an appropriate title, stating horizontal and vertical scales.

NOTE. Use pen and ink to finish drawing. The water may be colored a very light blue. The land may be shaded with a lead pencil. Space above land and water should be left without shading.

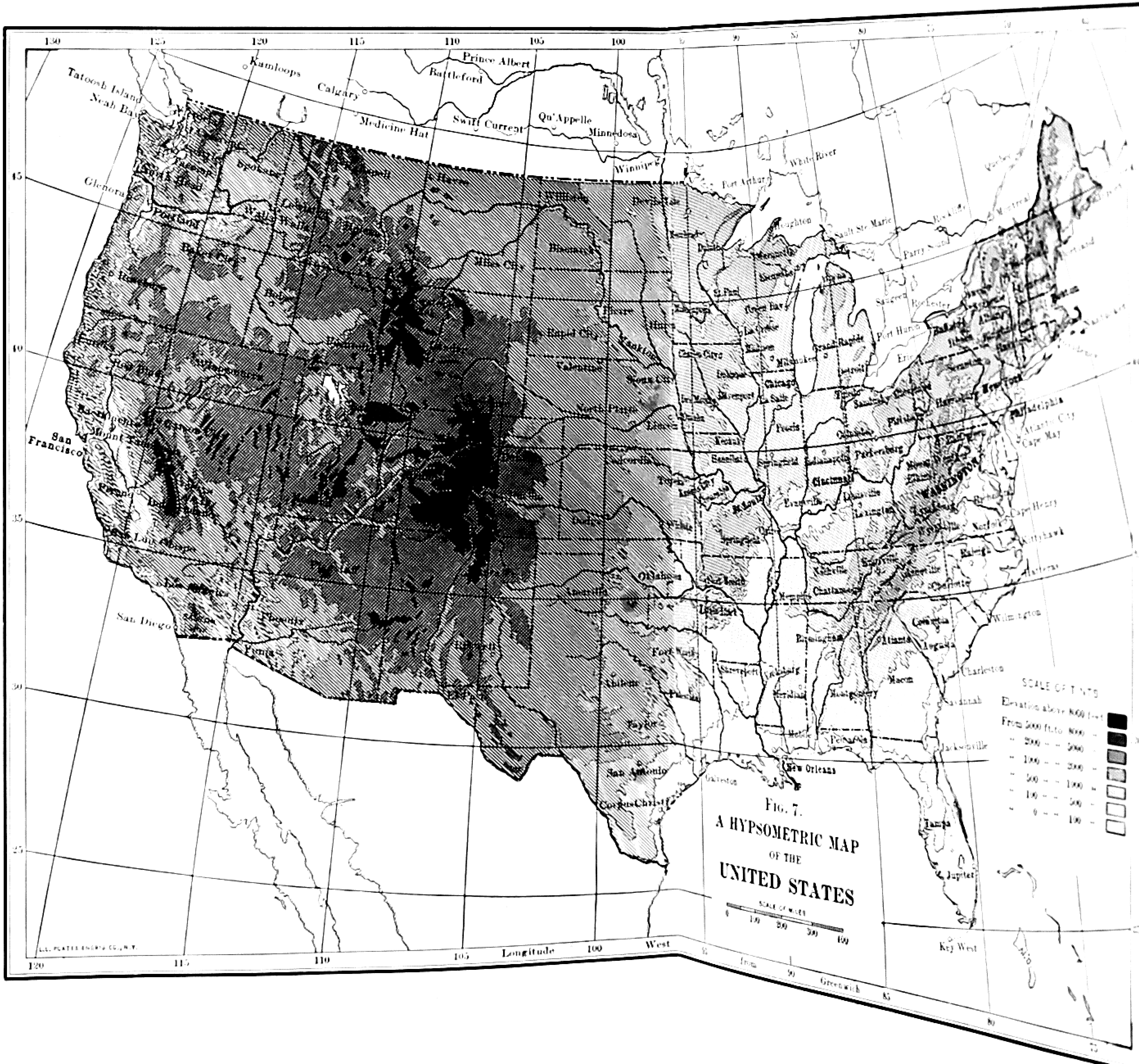

Fig. 7.
A HYPSOMETRIC MAP
OF THE
UNITED STATES

EXERCISE XXIX

CONTOUR LINES

Part I

Shape a sand hill on the table so that you will have a ridge extending in one direction from the summit, and one or more small streams flowing down the sides. Place a block one inch thick on the table and lay a long straight pointer on top of it. Move the block and pointer so that the end of the pointer will just touch and make a mark on the side of the hill. Move the block and pointer around so that a continuous line will be traced. This is a *contour line*. Place another block under the first, so that the pointer will be two inches from the top of the table, and trace another line around the hill. Repeat the process, adding one block at a time, until the top of the hill is reached.

Draw a map of the surface as you would see it looking from above. Use the scale most convenient. Give your map a title, stating that it was made in the laboratory.

Part II

Write a paper as follows:

Define contour line. A *contour interval* is the vertical distance between two contour lines. What is the contour interval in the contour map of the sand hill? How does the land lie where the contour lines are near together? where they are far apart? When contour lines cross a stream do they bend up the stream or down the stream? When contour lines pass around a ridge do they bend toward the summit or away from it?

Part III

Answer the following questions by referring to the picture, contour map, hachure map, and profile (Figs. 8–11). After

each answer put in parentheses a word which will tell from which of the four you could secure the desired information. (1) Give height of cliff at *A*. (2) Determine the shortest horizontal distance from *A* to the sea. (3) How many streams flow

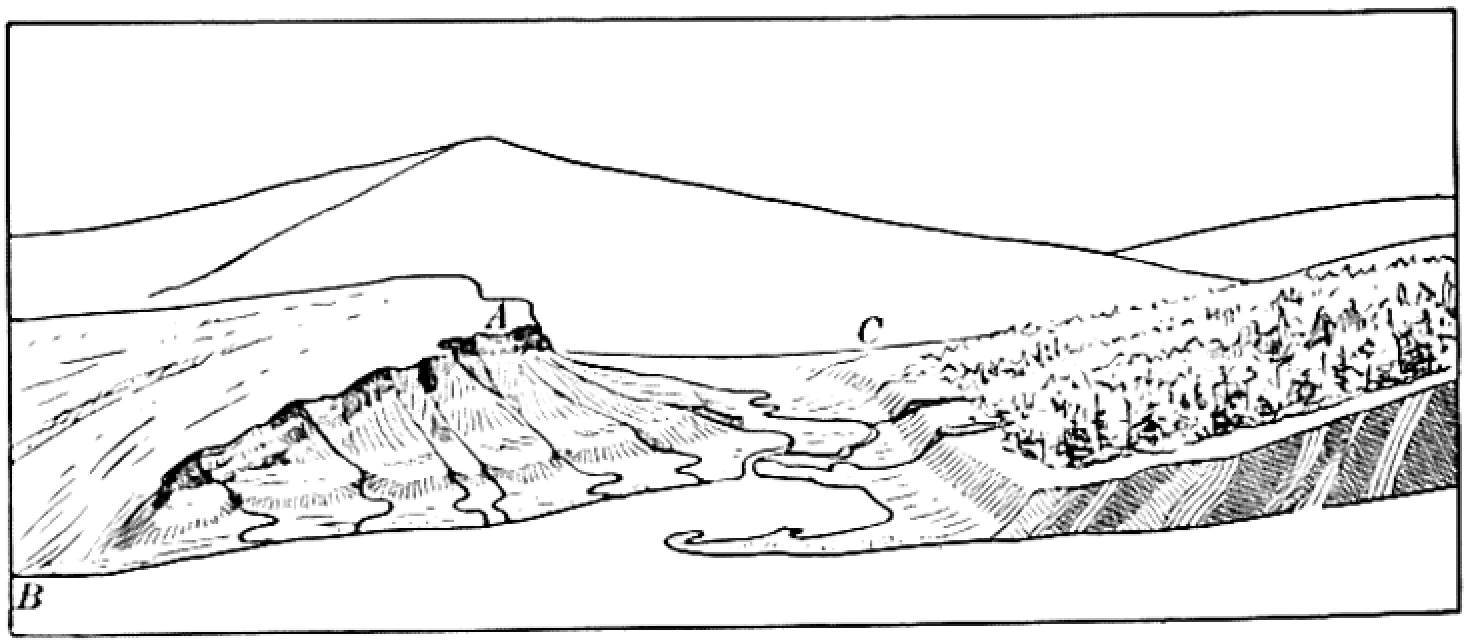

Fig. 8. A Landscape

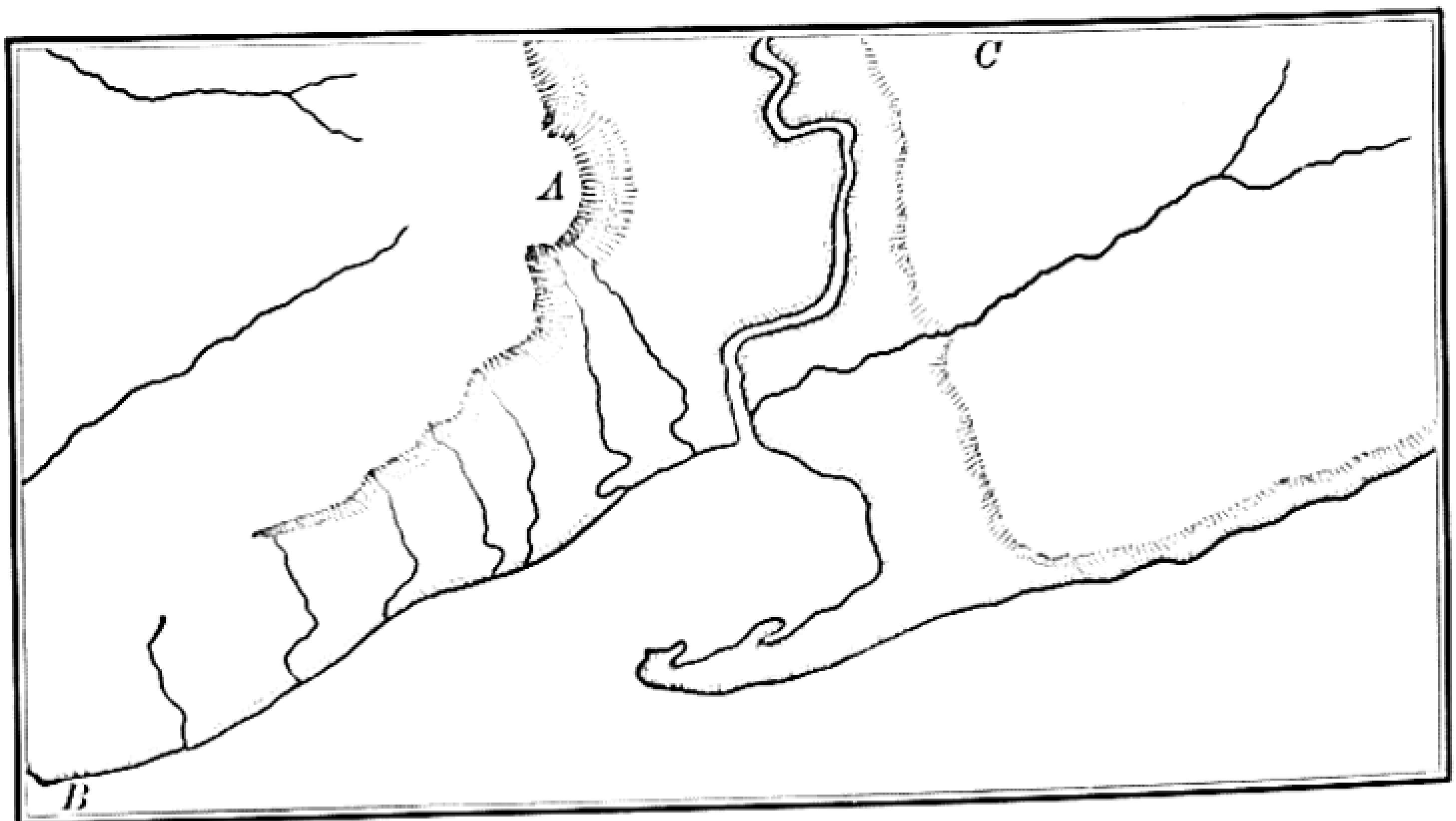

Fig. 9. A Hachure Map of the Region shown in Fig. 8

into the sea? (4) It is desired to make a road in a straight line from *B* to *C*, having a uniform grade. How deep will the deepest "cut" be? How far will the roadbed be above the bed of the large stream? (5) In which direction does the land slope between *A* and *B*? (6) What portion of this region is forested?

From which of these sources can you determine vertical distances accurately? horizontal distances? In what respects is the contour map superior to the hachure map? In what respects is the picture superior to either? In what respects is it inferior to either?

FIG. 10. A Contour Map of the Region shown in Fig. 8

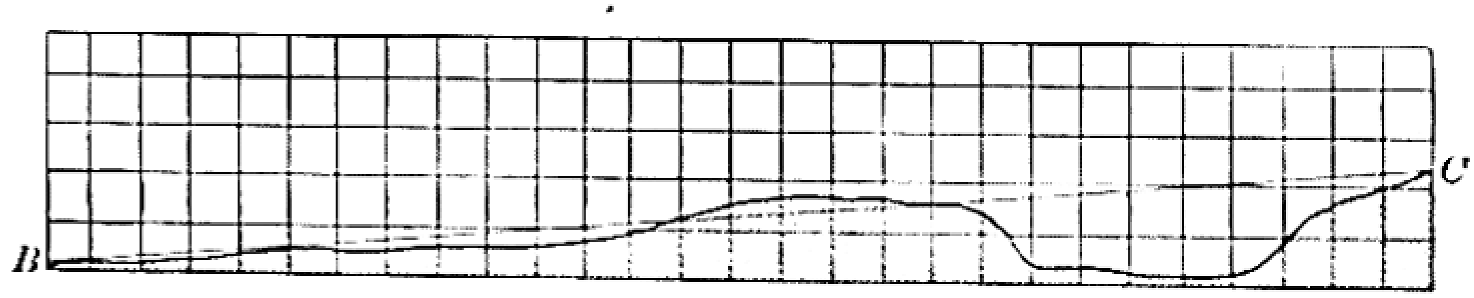

FIG. 11. A Profile drawn from B to C in Fig. 10

EXERCISE XXX

CONTOUR MAPS

PART I

Visit a small stream which you can easily walk across. Make a map of the region, showing the stream, its tributaries, the roads, buildings, and other prominent landmarks. Use two parallel lines just as close together as you can draw them to represent the roads. Indicate the cardinal points.

Walk across the stream, always keeping on the same horizontal plane. In crossing, do you go up the stream or down the stream? Walk for a considerable distance, always keeping on the same horizontal plane. Does your path lead you from the bed of the stream or nearer to it? Draw a line on the map, tracing the path along which you have walked. This is a contour line, if you have not departed from a horizontal plane. Draw other contour lines both above and below this one, using a contour interval of 10 feet.

When in doubt as to the height of a point, walk to it and compare its height with that of a known point. Levels may be determined by the use of the clinometer. Give your map an appropriate title, saying that it was made in the field.

Part II

Refer to the map, Fig. 12. Use cross-section paper and draw the profile along an imaginary line extending from *A* to *B*. Use the same horizontal scale as is used on the map; vertical scale one square to 100 feet. Make a rectangle around your drawing and put figures in the proper places to indicate elevations. Mark the ends of the profile with letters indicating the proper directions. Give your drawing a title, telling from what kind of map it is made. State vertical and horizontal scales.

EXERCISE XXXI

THE WEATHERING OF ROCKS

Part I

Use a brass ball and a ring which is just large enough to slip over it readily. Heat the ball in the flame of the Bunsen burner. Try to put it through the ring. What change has occurred? Account for this change. Let the ball cool and try again. What change do you observe? What effect has heat upon brass?

Use the apparatus consisting of a freely moving lever, with a tense rubber string on the long arm and an iron wire on the

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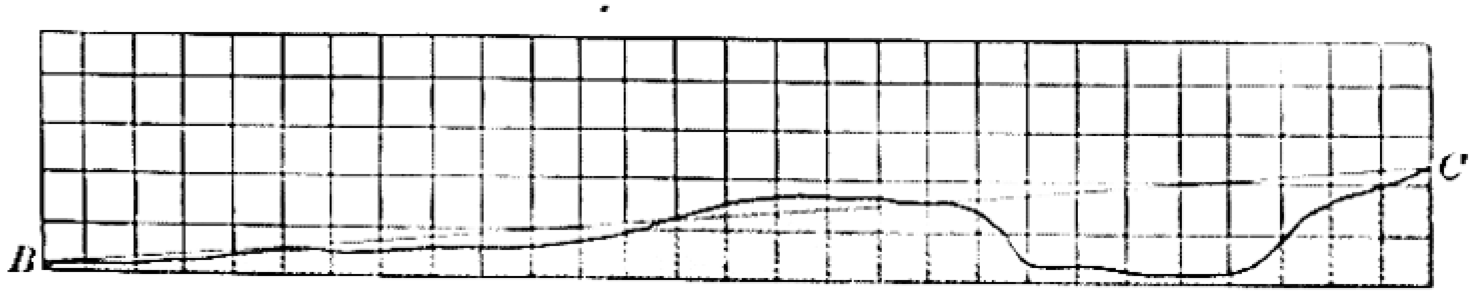

FIG. 11. A Profile drawn from *B* to *C* in Fig. 10

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CONTOUR MAPS

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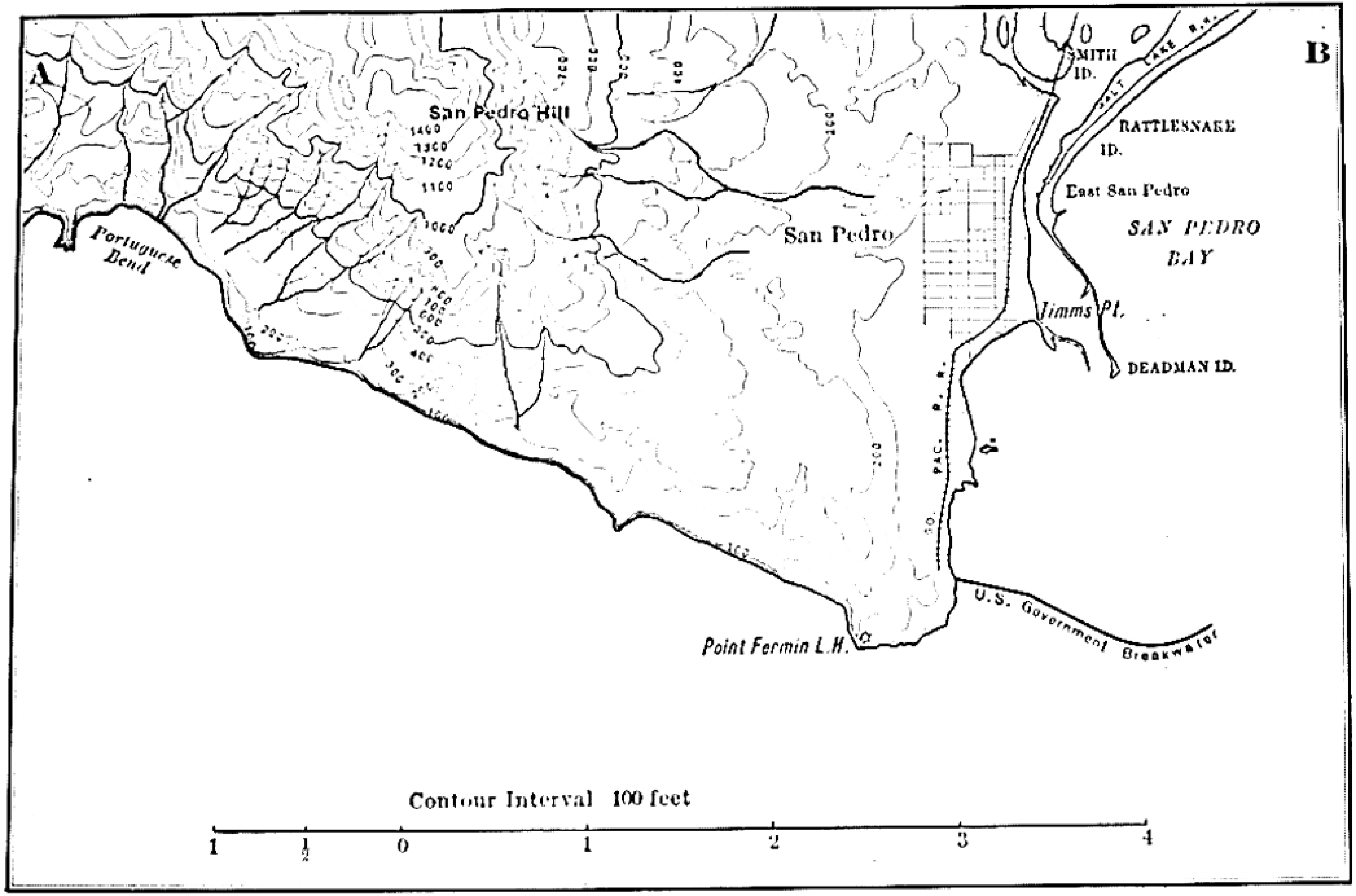

Fig. 12. A Contour Map of San Pedro Hill, near Los Angeles, California

other. (See Fig. 13.) Heat a portion of the wire by burning a match under it. What effect has heat upon iron? How do iron and brass act upon cooling?

What effect do you suppose heat would have upon a rock? How would a rock probably act upon cooling? Do rocks exposed on hillsides suffer change of temperature? How warm do rocks

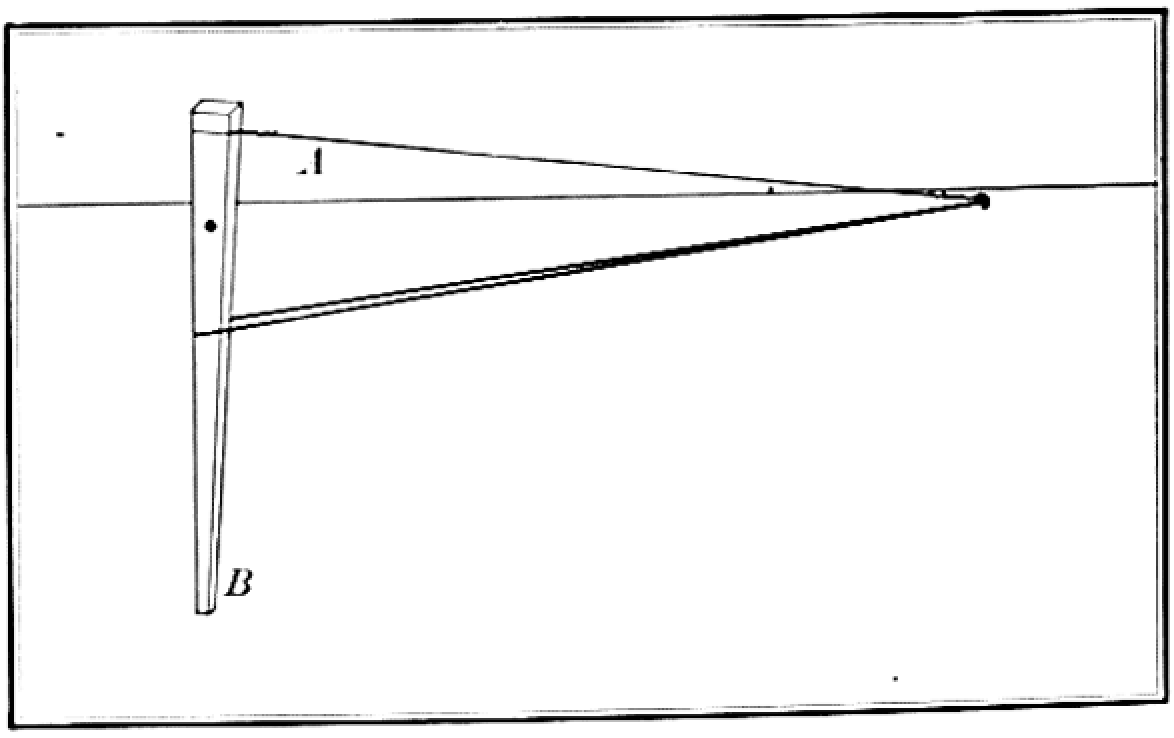

FIG. 13. Apparatus for showing the Effect of Heat on Iron

Apply a match below the wire at *A* and observe the movement of the lever at *B*

become when subjected to the heat of the sun during midsummer? Do you think the change of temperature from summer to winter would change the length of a rock half a mile in length? Which would be affected more, layers of rock on the surface or layers of rock underneath these?

PART II

Make a freezing mixture consisting of two parts ice to one part salt. Allow it to stand until the brine is two or three inches deep. Fill a small test tube half full of water and put it in the freezing mixture, being careful not to allow any of the salt or brine to enter the test tube. Be sure that the water line in the test tube is below the level of the brine. Let it stand until it is frozen. Examine the test tube. What has occurred? Account for this.

. Water enters the minute crevices of rocks, fills small cracks, and freezes. What effect must this have upon the rock? What portion of the rock will it affect the most? Will a stone monument endure longer in a moist or a dry climate?

EXERCISE XXXII

THE ASSORTING POWER OF WATER

Mix clay, sand, and gravel. Put them in a bottle of water and shake well. Let the mixture stand for a time and watch the settling process. Which of the solids settles first? Let the bottle stand over night and observe again. Which settles last? Make a drawing of the bottle, sediment, and water.

Arrange an artificial stream with a steep slope in its upper course and a gentle slope in its lower course. Into the upper course put slowly some of the mixture of clay, sand, and gravel. Which one is deposited first? Why? Which is carried farthest? Why?

Look for a stream in which the above conditions exist, that is, one that changes from a steep slope in its upper course to a gentle slope in its lower course. Do you find a deposit of sediment? Do you find materials deposited in order, as you did with the artificial stream? If so, make a drawing or a map, indicating by dots, circles, or angular figures the size, shape, and distribution of the material.

When a stream flows into the ocean, which part of its load do you think it deposits first? Which part is deposited farthest from shore?

EXERCISE XXXIII

EXAMINATION OF ROCK WASTE

PART I

Examine a rocky cliff in a place where there has been no disturbing influence which would remove material from the base of the cliff. Of what is this collection of material made

up? Examine the sand and gravel found here. What is the color? Is it clean or dirty? Are the edges sharp or rounded? Do you find any vegetable matter mixed with the sand and gravel? Do you find any very fine particles which, if carried away by water, might form silt?

Part II

Visit the bed of a stream which has recently contained a somewhat brisk current. Locate a place which has sand and pebbles. Give the color of the sand and pebbles. Are they clean or dirty? Are the edges sharp or rounded? Do you find any vegetable matter mixed with the sand and pebbles? Do you find any very fine particles which you might call silt? Compare each answer with the corresponding answer in Part I, and account for any difference.

If a stream carries much sand and gravel, what effect will it have upon the rocks over which it flows? How will this affect the sand and gravel?

EXERCISE XXXIV

A WATERFALL

Locate by map or description the waterfall which you examine. Locate the gorge with reference to the fall. What agent has been most effective in making the gorge? What has become of the material which has been removed? Which resists erosion better, the rock over which the water is falling or the material beneath this rock? Compare the fall rock with the material underneath. What difference in structure would produce rapids instead of a waterfall? What effect is the flowing water having on the fall rock? What aids the water in this work? Has the fall always been at this point? What effect will a continued flow of water have upon the location of the fall? Define *migration* as applied to a waterfall.

Use cross-section paper and draw the following sections, using suitable horizontal and vertical scales: (1) cross section of the

gorge and stream below the fall; (2) cross section of the gorge and stream above the fall; (3) longitudinal section of the gorge and stream through the fall. In drawing the longitudinal section do not represent the sides of the gorge. In all sections indicate the nature of the soil or rock by signs or shading chosen for the purpose. Give proper titles to your sections and indicate the scale.

If no waterfall is accessible, refer to the Canyon (Wyo.) sheet (topographic map of the United States Geological Survey) and make the sections called for, using suitable horizontal and vertical scales. Answer as many of the questions as you can by referring to the map, or from other sources of information.

EXERCISE XXXV

RIVER FLOOD PLAINS

Part I

Visit a river bottom. Describe color, texture, and depth of the soil. Is bottom land considered good farm land? Why? How does it differ from the adjacent higher land? Do you find any pebbles, bowlders, or other rounded rocks in the soil? If so, how do you suppose they came to be there? How high does the water come in the times of the highest floods? Does it make any deposit at this time? If so, what is the nature of the deposit? How wide is this bottom or flood plain from bank to bank?

Part II

Refer to the Donaldsonville (La.) sheet, topographic map of the United States Geological Survey. Give approximately the area in square miles of the region represented. (See the scale at the bottom of the sheet.)

What river is here shown? What portion of the river? Locate Donaldsonville with reference to New Orleans. What portion of this quadrangle is a swamp? That part between the river and the swamp is the natural levee. How wide is

the natural levee, measuring across the river? How high is it above the swamp? What was the active agent in the formation of the natural levee? Explain why it is higher than the swamp. What direction do the small streams take? Why do they not flow toward the river? Into what do they finally flow? Are the swamps of any value to men?. Of what disadvantage are they? Could they not be drained and utilized?

What is the contour interval of the map? (See the bottom of the sheet.) How can you distinguish a steep slope from a gentle one by aid of the contour lines? (See Exercise XXIX, Part II.) Compare the steepness of the slope of the levee at Nita crevasse with the steepness just above or just below the crevasse. An artificial levee has been built at Nita crevasse. How long is the artificial part? (You can tell by its being so much narrower than the natural levee.) How high above the wagon road is the artificial part? What have you read about artificial levees elsewhere on the Mississippi river? What kind of formation do you find in the margin of the swamp northeast of Nita crevasse? Account for this. Read about the Nita crevasse in Davis' *Elementary Physical Geography*, pp. 264–265. Record what you read, putting it in your own words, but telling where you obtained the information.

Where are most of the houses in this quadrangle situated? Compare the direction of the railroads and the general course of the stream. What is the principal industry of this region? (See p. 4 of Folio 1, and give the source of your information.)

PART III

Fig. 14 shows a part of the narrow flood plain of the Merced river in the Yosemite valley. Of what kind of material does the soil seem to be composed? What evidences of fertility do you observe? How many feet must the river rise in order to overflow the flood plain? In what time of year is this most likely to occur?

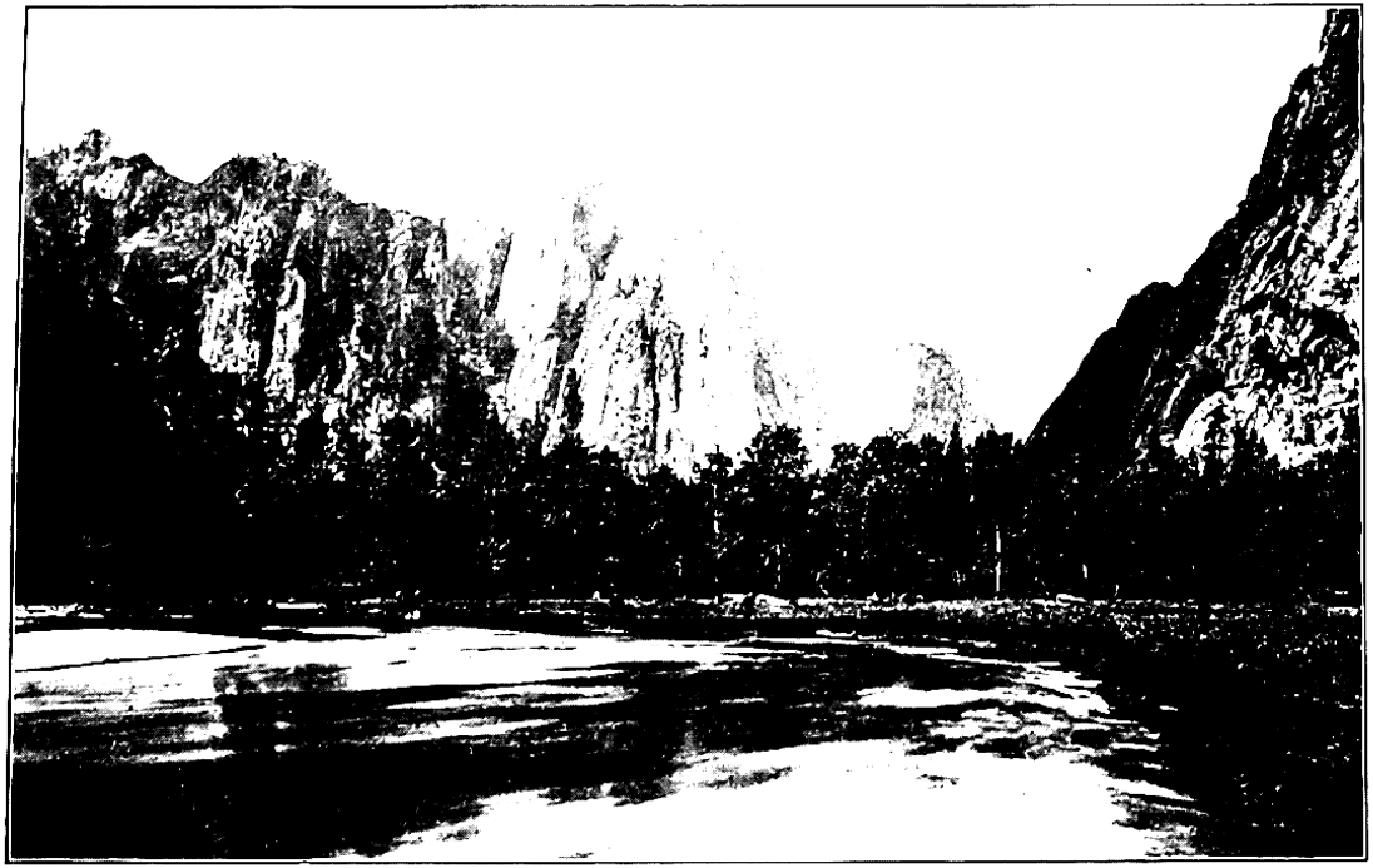

FIG. 14. The Flood Plain of the Merced River, Yosemite Valley, California. (Looking downstream)

The river here makes a bend. A sand bar is shown at the left

EXERCISE XXXVI

MEANDERS

Part I

In the river flood plains which you visited in Exercise XXXV, nearer which bluff (right or left) does the river flow? How near does it approach this bluff? Does the river cross the flood plain? Does it make large S-shaped curves? What name is given to such curves? Observe the banks of the river near the sharpest point of a curve. Is the bank precipitous on the inside or the outside of the curve? Describe the lay of the land which forms the bank on the inside of the curve. Of what kind of material is it composed? Near the point of the curve does the main current of the river flow nearer the inside bank or the outside bank? Which bank will it erode more rapidly? Does it make a deposit along either bank? If so, on which side of the curve? Why does it deposit material on this side? Will continued erosion by the river tend to make the curve more or less pronounced?

Note. A stream may be so small and narrow that you can step across it, and still it may have such curves as are discussed in this exercise.

Part II

In what part of Missouri is Marshall? How far is it from St. Louis? In which direction does the river flow in the region represented on the Marshall sheet? (See topographic map of the United States Geological Survey.) Measure the entire length of the river represented here, following the main channel. Also measure the distance straight across and compare the two measurements. How wide is the river bottom or flood plain from bluff to bluff, just south of Carrollton? at Miami? at Brunswick? at New Frankfort? About what is the average width? How many times does the river bend toward the north bluff? the south bluff? What name is given to these big S-shaped

curves? Why does the river follow such a crooked course instead of flowing in a more direct one? Why is it called a graded river? What is meant by *base level of erosion?*

On which side of Prunty island does the principal part of the stream flow? Observe the sand in this part. Is it on the inside or outside of the curve? On which side of the curve (inside or outside) is the main channel? At the following bends in the river observe on which side the deposit of sand is found, and on which side the main channel is found: (1) between Prunty island and Miller island; (2) north of Miami; (3) northeast of Dewitt. Do you find it the same in each? Did you find it the same in Part I? Why is the sand deposited on the side on which you find it rather than on the other? On which side does the river flow more swiftly? On which side will it cut the bank more rapidly? What effect will this have on the size of the S-shaped curves? Observe the sharp curve near the east side of the quadrangle. What will be the fate of the peninsula projecting from the south side? What will be the fate of that portion of the stream north of the peninsula? How were Davis lake, Backbone lake, and Grand Pass lake formed?

Do you think erosion is greater on the bottom or the sides of the channel? Is the rate of erosion of the stream greater or less than the rate of deposition? What kind of material do you think is deposited here? Would such deposit make fertile soil? Do you think of any disadvantages that the owner of a farm in the bottom might suffer? Judging by the number of towns and villages, do you think this region is thickly settled?

Part III

Examine Fig. 14 and describe everything you see which is similar to the river forms discussed in Parts I and II of this exercise. How will the trees affect the rate of cutting of the bank by the stream?

EXERCISE XXXVII

ALLUVIAL CONES

In what part of California is the region represented by the Cucamonga sheet? (See topographic map of the United States Geological Survey.) Pomona is the largest town shown on the sheet. How far is it from Los Angeles? What portion of this region is mountainous? In what direction is the general slope in the southern part of this quadrangle?

San Antonio canyon is a deep and narrow gorge cut in the southern slope of the mountain range. From an elevation of 2600 feet down to the mouth of the canyon (2250 feet) the creek has deposited great quantities of bowlders, pebbles, and other materials. This is called a *wash.* How is it represented on the map? Account for this deposit. How far south of the mouth of the canyon can you trace the wash? Describe the general shape of the contour lines for several miles south of the mouth of the canyon. Does this indicate that the land surface is convex or concave? The San Bernardino base line crosses the 1500-feet contour line north of North Ontario and again north of Claremont. What is the elevation of the base line midway between these two points of crossing? Does this prove or disprove your statement about the convex or concave surface which is represented here? Are river valleys usually convex or concave? Why is this one as it is? What name is given to such a land formation? Of what kind of material is it composed? What difference in kind of deposit would you expect to find in the wash within the canyon and on the slopes at Pomona and Ontario? (See Exercise XXXIII.) Is the soil at the latter places fertile? How do you know? Describe the wash from the mouth of the canyon to the town of Claremont and the A. T. & S. F. railroad. What name is given to the smaller, branching parts? Account for their formation. In what respects is an alluvial cone similar to a delta? In what respects is it different?

Near the point where Stoddard canyon enters San Antonio canyon the stream becomes intermittent, and near the mouth of the canyon it disappears altogether. What becomes of the water? Between Pomona and Chino a little stream rises. Where does the water probably come from? Throughout this alluvial cone much water is pumped from deep wells and is used for irrigation. Where does this water come from?

Determine the elevation of the bed of the stream where Bear canyon enters San Antonio canyon. What is the fall in feet

FIG. 15. A Débris Fan at Glenwood Springs, Colorado, formed at the Mouth of a Side Gorge

Grand river in the foreground

from this point to the mouth of San Antonio canyon? What is the average fall in feet per mile? What is the average fall in feet per mile from the mouth of San Antonio canyon due south to the edge of the map? Which is the steeper slope, above or below the mouth of the canyon?

Name the canyons represented on the Cucamonga sheet, whose streams are building up cones. What does the author

of Folio 2 say about the extent of alluvial cones in southern California and elsewhere? Give the conditions of slopes and climate which are favorable to the formation of alluvial cones.

Fig. 15 shows a débris fan or alluvial cone formed by a tributary of the Grand river, at Glenwood Springs, Colorado. About what angle does the slope of the fan form with the horizontal? What, if anything, is there here which would lead you to believe that the slope of the side canyon is steeper than that of the fan?

EXERCISE XXXVIII

A REGION IN YOUTH

Locate Yellowstone park on a large map of the United States. Give the part of the state in which it is located. What stream drains Yellowstone lake? What is the general direction of that portion of the stream which is shown on the Canyon sheet? (See topographic map of the United States Geological Survey.) Into what does this river flow? What is the elevation above sea level of the surface of Yellowstone lake? (See small brown figures near the printed name.) What is the elevation of the river at the lowest point shown on this map? (Count down from the contour line of 6000 feet.) Measure in miles the length of this portion of the river and calculate the fall per mile.

How many miles from Yellowstone lake are the falls? Give height of each of the falls. The Grand Canyon of the Yellowstone begins at the falls. How deep is this canyon opposite the letter *a* in the word "canyon"? How wide is it at this point? Does this river have a flood plain? Which is probably greater, the rate of erosion or of deposition? Is the stream capable of carrying a large load? Give reasons for your answer. What effect will continued erosion probably have upon the width and depth of the canyon?

Count the number of tributaries on one side of the Yellowstone river from Yellowstone lake to the northwest corner of

the quadrangle, omitting those not named. What is the average distance in miles between the mouths of these tributaries? If Yellowstone river deepens its channel at the outlet of the lake, how will the water level of the lake be affected, all other conditions remaining unchanged? If the falls should migrate as far upstream as the lake and disappear in the lake, how would the water level of the lake be affected, all other conditions

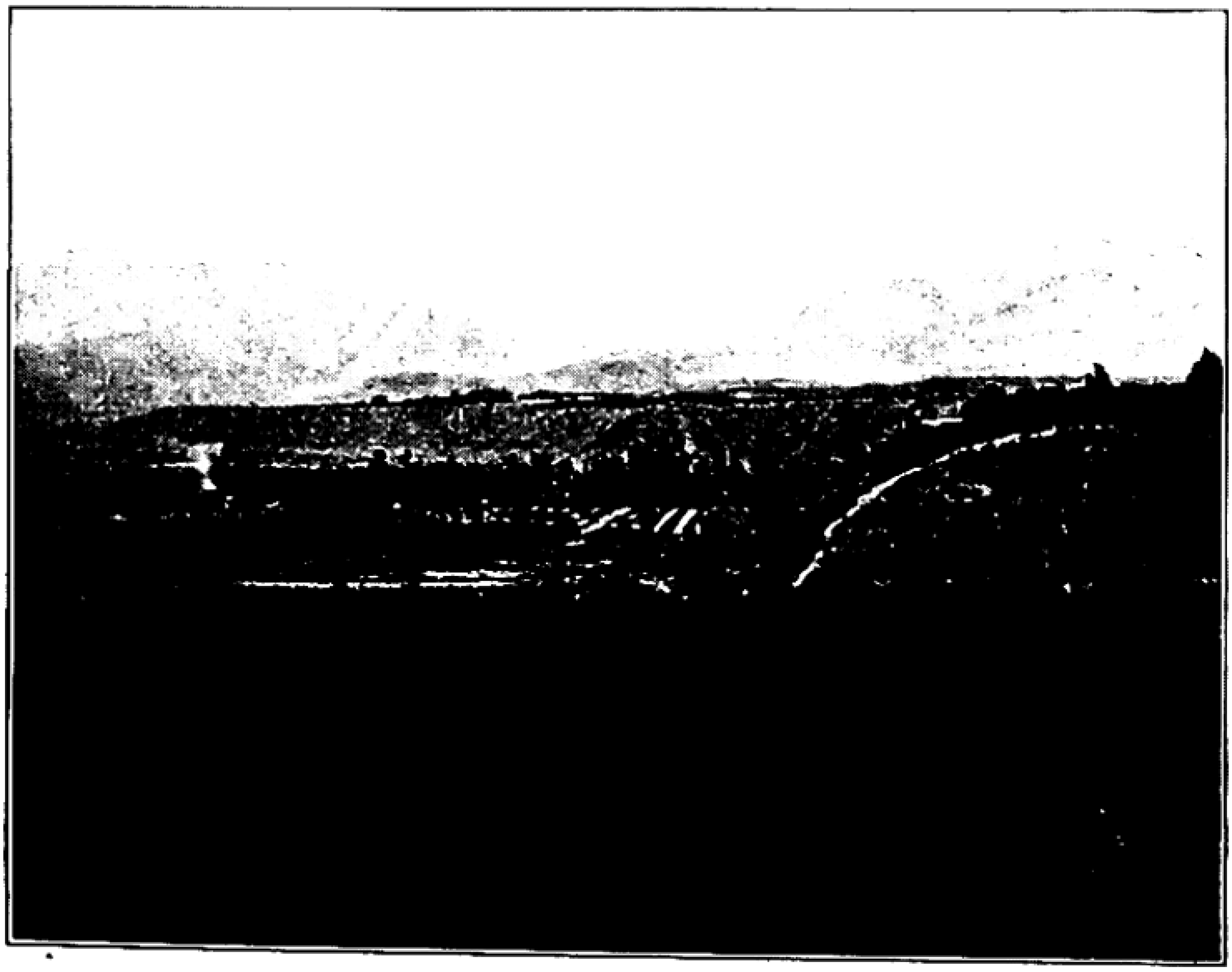

FIG. 16. A Terrace, 150 Feet in Height, cut by the Santa Ana River, Southern California

Some of the best orange groves in the world are located on this terrace

remaining unchanged? Lakes are an evidence of uncompleted work or imperfect drainage. What other evidence of imperfect drainage do you find on this quadrangle? (Look along Pelican creek, which flows into Yellowstone lake, and along Slough creek, in the extreme northern part of the quadrangle.) If draining this region were the task of the Yellowstone river, would you say it has much or little yet to do?

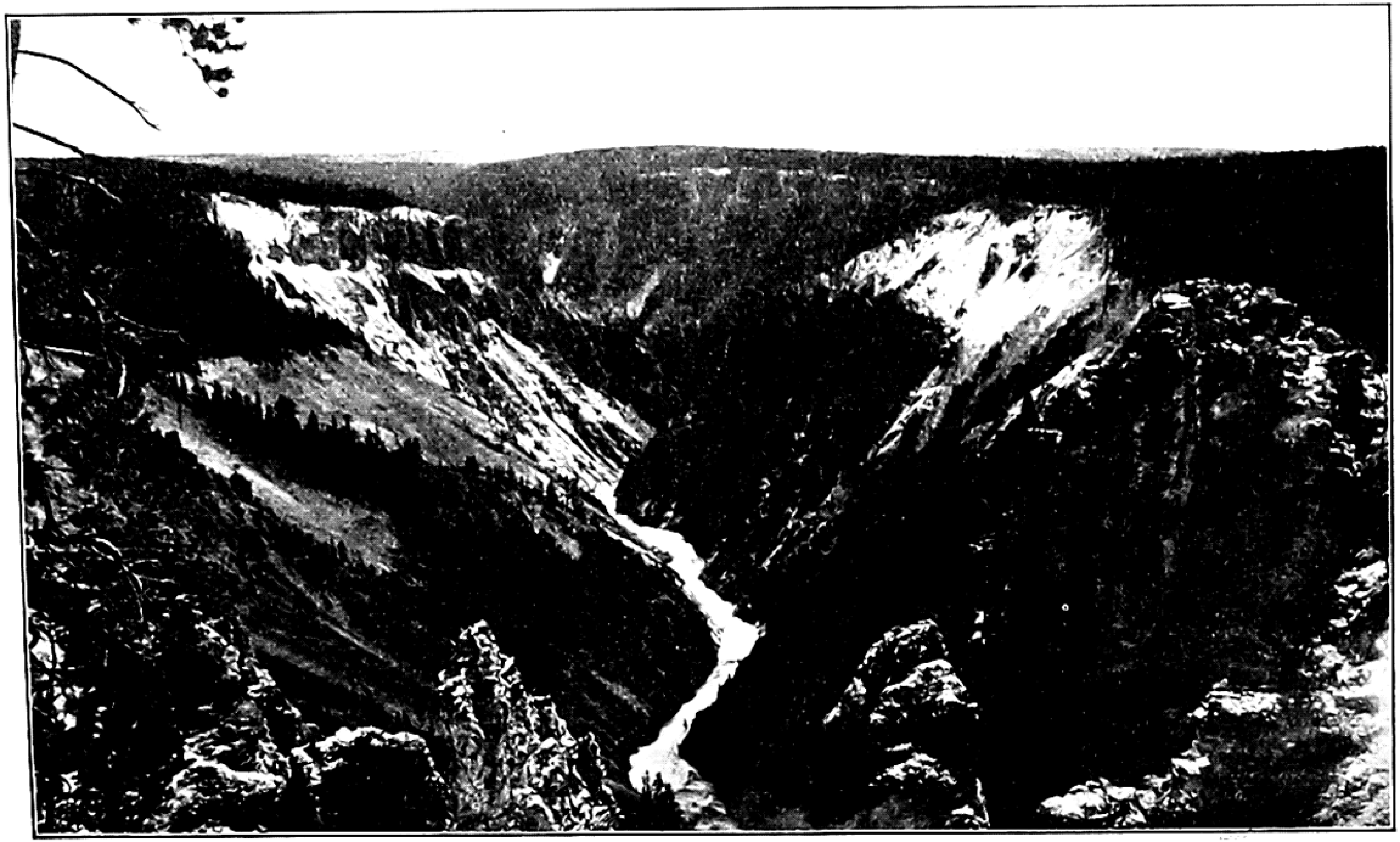

FIG. 17. The Canyon of the Yellowstone, showing the Surface of the Plain in which it is cut

The region represented on the large map[1] is a great plateau. It is being cut by canyons into smaller plateaus. Determine and record the average elevation of each of the following plateaus (see large map): (1) Buffalo plateau; (2) Mirror plateau; (3) Two Ocean plateau: (4) Pitchstone plateau; (5) Madison plateau; (6) Central plateau. Which is highest? Do you detect any slope away from this plateau? If so, in what direction? Observe the picture of the canyon of the Yellowstone. (See Fig. 17.) The background represents one of these plateaus. Describe the sky line. If one were standing on this plateau, the higher portions would appear as mere undulations of the surface. Distant canyons would not be visible. Why? What effects will continued erosion probably have upon the general appearance of this plateau?

Why is it appropriate to say that this stream and this region are in their youth?

EXERCISE XXXIX

A REGION IN MATURITY

Part I

Locate Charleston (W.Va.), giving the river on which it is located and the distance from the point where it flows into the Ohio river. Count the tributaries on one side of the Kanawha below Charleston (see the Charleston sheet, topographic map of the United States Geological Survey), omitting those without printed names. Are any of them intermittent? What would you infer about the rainfall of this region? Measure the distance along the river from Charleston to the last tributary which is shown. Give the average distance in miles between tributaries. Compare this with that shown on the Yellowstone canyon sheet.

What is the contour interval? Are the contour lines near together or far apart? If the contour interval were 20 feet, as

[1] Assembled topographic sheets of the United States Geological Survey, as shown on page 170.

it is on some sheets, would the lines here be more or less numerous? Would they be nearer each other or farther apart? Are the sides of the valleys steep or gentle in slope? Are the divides pronounced or indistinct? Is the drainage perfect or imperfect? Characterize this region as *level*, *rolling*, or *broken*.

What kind of soil has this region? Give reasons for your answer. In what direction do the wagon roads run? Why? How far across country could one go without crossing a wagon road? Do you think this region is thickly or sparsely settled?

Part II

Hickory Knob is about two miles from the north boundary of the quadrangle and five miles from the west boundary. Its elevation is printed in brown just above the name. How high above sea level is it? Find the elevation of the following knobs, which are nearly in a straight line extending south from Hickory Knob, and make a list of them with their elevations: (1) Hickory Knob; (2) Big Rocks, about nine miles south of Hickory Knob; (3) Sugar Camp Knob, nine or ten miles south of Big Rocks; (4) Blue Knob, five miles southwest of Sugar Camp Knob; (5) an unnamed knob about three miles from the southwest corner of the quadrangle. Suppose this region was once a plateau as high as the tops of these knobs, and suppose the original plateau restored as it was at that time. How high was the plateau at the south? at the north? Which way did it slope? What was the fall per mile? Does the Kanawha river now have as great a slope as the plateau that you have described?

The highest point near the southeast corner of the quadrangle is in Fork Ridge, three miles from the east boundary and seven or eight miles from the south boundary. How high is it? Compare this with the elevation of Blue Knob, which is almost due west of Fork Ridge. The highest point near the northeast corner of the quadrangle is about 1300 feet above sea level. Compare this with the elevation of Hickory Knob at the northwest corner. Do you detect a slope toward either east or west? What was

the true direction of the slope of the original plateau? Compare this with the general direction of the Kanawha river. Henry Gannett says that this region was once just such a plateau as we have described. How has it been changed from a plateau to the skeleton of a plateau that you now see on the map?

EXERCISE XL

A REGION IN OLD AGE

In what part of Kansas is Caldwell? What is the contour interval of the Caldwell sheet? (See topographic map of the United States Geological Survey.) If the contour interval were 100 feet, as it is on the Charleston sheet, how would the number of lines here compare with what it is? Are the slopes gentle or steep? Are the valleys wide or narrow? Are the divides pronounced or indistinct? How is it possible to build railroads in so many different directions? What directions do the wagon roads take? How far apart are they? In which does the land lie better for farming, this or the Charleston quadrangle?

The author of this folio tells us that the Caldwell region has gone through the stages of youth and maturity. What proof of this does he find in the position of the rocks? What is a peneplain? (See the text-books.) What is meant by *base level of erosion?* Account for the big bends in the Chikaskia river below Argonia. Account for the lake or pond just west of Caldwell.

In this region the average annual rainfall is about 20 inches, an amount very much less than that of the Charleston quadrangle. In which region would erosion be greater if it depended upon this alone? In the Caldwell quadrangle the surface of the land is almost naked, whereas in the Charleston quadrangle it is covered with dense forests. In which region would erosion be greater if it depended upon this alone? In the Caldwell region the underlying and outcropping rocks are much softer than those of the Charleston region. In which would erosion be greater if it depended upon this alone? In which would it be greater if it depended alone upon the steepness of the slopes? Which of

these conditions of erosion can man modify? What effect does erosion have upon the fertility of the surface that is being eroded?

EXERCISE XLI

THE LIFE HISTORY OF A RIVER

Make an outline of the life history of an ideal river. Make it in three parts as follows: (1) a young river; (2) a mature river; (3) an old river.

In each part consider: (1) steepness of slope; (2) swiftness of current; (3) character of load; (4) cutting power; (5) number of tributaries; (6) shape of cross section of valley; (7) perfect or imperfect drainage; (8) fall per mile from source to mouth; (9) longitudinal profile; (10) presence of lakes, canyons, waterfalls, rapids, flood plains, meanders, delta.

EXERCISE XLII

THE DRAINAGE AREAS OF THE UNITED STATES

Use an outline map of the United States and draw the divides around the following drainage basins: St. Lawrence, Mississippi, Columbia, Colorado, Great Basin. Draw also the divides bounding the following slopes: Atlantic, Gulf of Mexico east of the Mississippi river, Gulf of Mexico west of the Mississippi river, Pacific slope.

Color these regions so that no two adjacent shall have the same color. Rub in the colors well. Write an explanation of colors, or legend, in an appropriate place on the map.

EXERCISE XLIII

THE MIGRATION OF DIVIDES

What large river is shown on the Doylestown (Pa.–N. J.) sheet? (See topographic map of the United States Geological Survey.) About how far from Philadelphia is this portion of the river? In what direction from Philadelphia?

Tinicum creek flows into Delaware river near the northern boundary of the quadrangle. It is a crooked stream, flowing first toward the southeast and then toward the northeast. What is the elevation of the first point of its headwaters, which is shown on the north side of the map? What is the average fall in feet per mile?

Tohickon creek is a very much longer stream, which flows into the river at Point Pleasant. What is the elevation of the first point of this stream, which is shown on the west side of the map? What is the rate of fall? Which is the more vigorous stream, Tohickon or Tinicum creek?

Near the large bend in Tinicum creek there is a small tributary which enters from the southwest. This tributary has its headwaters near a fork in the road, about a mile and a half southeast of Ottsville. At this point the road is on the divide between Tinicum and Tohickon creeks. How high above sea level is the divide at this point? What is the elevation of Tohickon creek near this point? How many feet would have to be removed from the divide to make it the same level as the water in Tohickon creek?

Which stream will erode its basin more rapidly, all conditions except the slope being equal? What effect will this have upon the size of its basin? upon the size of the other basin? In which direction will the divide probably move at the point southeast of Ottsville? If the divide should move a mile in the direction which you indicate, what change would occur in the course of Tohickon creek? This action of the stream is called *beheading*. Which stream is in danger of being beheaded? How large an area in square miles is liable to be cut off in this way? Consider only the region shown on this map.

If these streams were furnishing power for manufacturing, how might the result of migration of divides affect the industry?

EXERCISE XLIV

SPECIFIC GRAVITY

With a string tie a stone to the hook on one pan of the specific-gravity balance. Weigh the stone. Place the balance and the stone in such a position that the stone will be completely immersed in a vessel of water, but do not allow the scale pan to touch the water. With the stone in the water, weigh it again. Does it weigh more or less than it did before? How much? Why does it weigh less under one condition than under the other?

If the stone should be removed, the space that it now occupies would be filled with water. At present it displaces the water. Compare the volume which it displaces with the volume of the stone. The volume of the water displaced weighs just as much as the difference between the two weights of the stone obtained above. You may be called upon to prove this some day; now we must accept it without proof. Give a rule for finding the weight of the water displaced by a stone immersed in it. Give a rule for finding the weight of water equal in volume to the volume of a stone.

Compare the weight of the stone with the weight of an equal volume of water. The ratio of the former to the latter is called the *specific gravity*. Define specific gravity. Give a rule for finding the specific gravity of a stone. The last rule is the important one. Remember it.

What is the specific gravity of a stone which weighs just as much as an equal volume of water? (If in doubt, assume that each weighs 50 grams, and calculate it according to your rule.) What is the specific gravity of a stone which weighs less than an equal volume of water? (Give answer as equal to, greater, or less than that of the preceding.)

In writing your notes draw or describe the apparatus.

EXERCISE XLV

VOLCANIC ROCKS

PART I

Examine obsidian, pumice, and vesicular basalt. Describe each according to the following schedule:

Color. Distinguish between dull black and lustrous black, between light gray and dark gray.

Structure. Is it solid, porous, fibrous, crystalline, or amorphous?

Weight. Give specific gravity.

Method of formation. Read text-books, reference books, cyclopedias, and dictionary.

Remarks. Anything that does not readily come under the items given above, especially locality from which your specimen comes.

PART II

Fig. 18 shows a mudhole which has dried up. Describe the effects which have been produced. How deep have you ever known such mud cracks to be? Fig. 19 shows a lava flow in which the cracks, or joint planes, extend very deep. Tell what you know of the cause of their formation.

EXERCISE XLVI

VOLCANIC PEAKS, PLATEAUS, AND NECKS

Refer to the Mt. Taylor (N. M.) sheet. (See topographic map of the United States Geological Survey.) In what part of New Mexico is Mt. Taylor? What is the highest point on the mountain? Two or three miles east of this highest point there is a stream formed by a dozen or more small tributaries. Trace with a pointer the divide surrounding the headwaters of these

tributaries. This divide is the rim of an ancient crater. What shape was the crater? How far is it from the rim on one side to the rim on the opposite side? At how many points about the crater does the elevation reach 11,000 feet? What is the elevation of the river bed at the point where it flows through the rim of the crater? Near the center of the crater is a circular hill. What is the elevation of its summit above sea level? How high is it above the stream which flows near its northern

FIG. 18. Mud Cracks in the Bed of an Intermittent Stream, Southern California

side? This hill is a *volcanic neck*. How has it been made? (See picture and cross section on the page opposite the map in Folio 2.) How deep is the crater from the rim to the small level area just west of the neck?

What is the average elevation above sea level of the mesa Sierra Chivato? of the region 10 or 15 miles northwest of Willow Spring? (Count down from the contour line of 7000

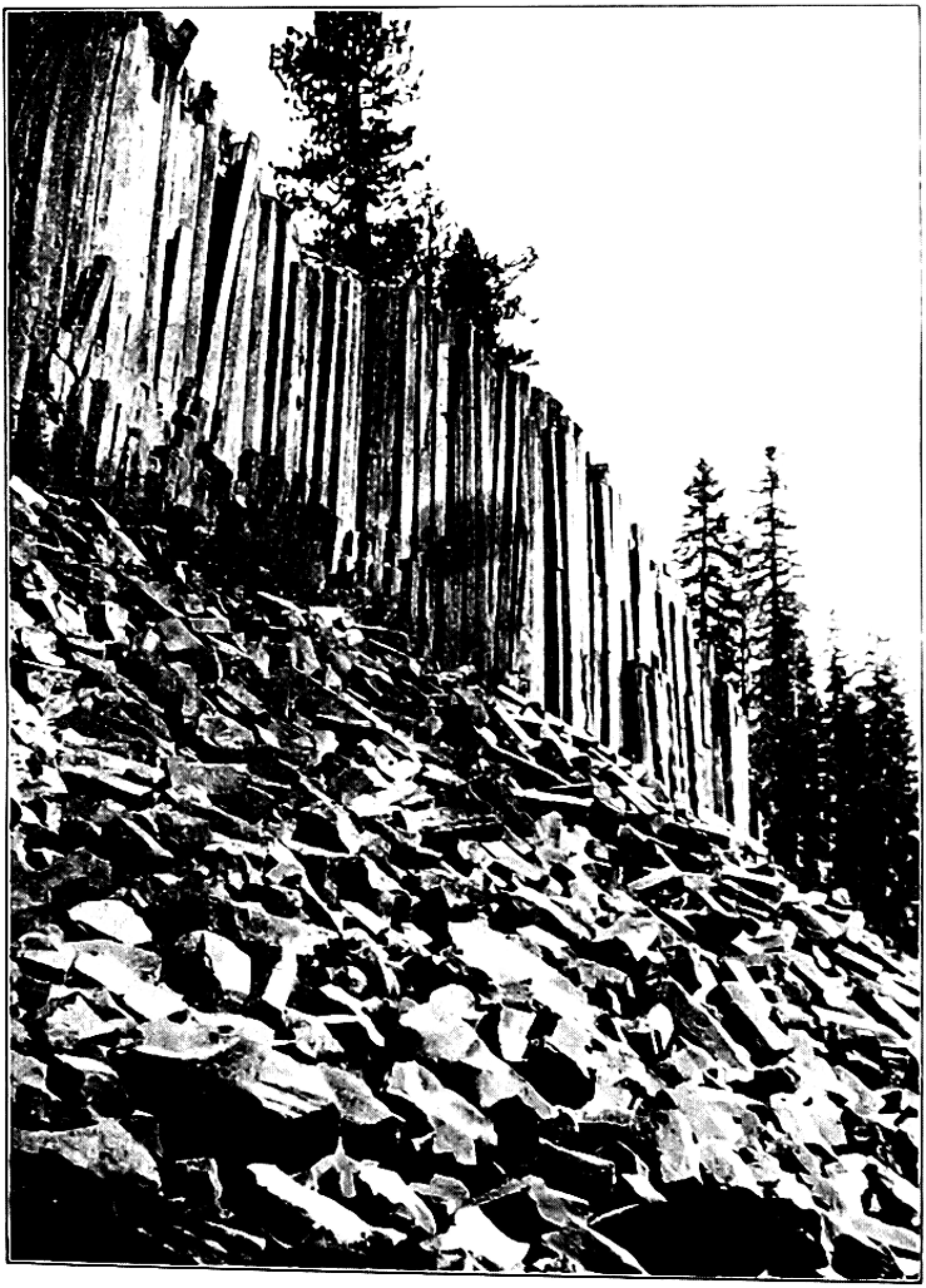

Fig. 19. Columns of Basalt from an Old Lava Flow on the North Fork of the San Joaquin River, California

feet.) How much higher is the mesa than the surrounding region? Is the descent from the mesa abrupt or gentle? With a pointer trace the outline of the mesa. In which direction does it extend farthest from Mt. Taylor? The author of Folio 2 says, "This is a volcanic mesa, formed by outflows of lava from the mountain and probably from other craters upon the surface of the mesa." Across the Puerco river northeast of the Sierra Chivato is Cabazon peak, a volcanic neck more than 1000 feet high. How many volcanic necks do you see between the Sierra Chivato and the Puerco river? Volcanic necks "were formed by the forcing of volcanic rocks, in a molten condition, up through overlying stratified beds. These beds, which were much softer than the lava, have since been eroded away, leaving the neck of lava standing by itself."

EXERCISE XLVII

A CRATER

Refer to the Crater lake (Ore.) special sheet. (See topographic map of the United States Geological Survey.) Locate Mt. Mazama. For what is it remarkable? What shape is Crater lake? What is the distance across it from east to west? How large is the drainage basin which contributes its waters to Crater lake? What is the highest point on the rim surrounding the lake? At what point would the water first find an outlet if the surface of the lake should rise above its present level? What is the elevation above sea level at the surface of the lake? How far is this below the top of the rim which surrounds the lake? Compare the steepness of the slope on the inside of the rim with that on the outside. Could one easily ascend these slopes? Where is the steepest part? See the picture of this steepest part on the page opposite the map in Folio 2.

Crater lake is most easily reached by a wagon road from the south, but there is a trail approaching it from the north. Compare the steepness of the lower part of the trail up as far as the first spring with the slope of a straight line from this spring to

Llao rock. Observe the section at the bottom of the sheet, use cross-section paper, and draw a similar section from north to south along the meridian of 122 degrees, 5 minutes. Let your section extend one mile beyond the lake both north and south. Use the same horizontal scale as on the map, vertical scale one square to 1000 feet. (Blue figures show depths in feet below the surface of the lake.)

How does the author of this folio account for the formation of Crater lake? If you have read anything else of special interest or value concerning this lake, record it here. Tell where you read it.

EXERCISE XLVIII

GLACIERS

Refer to the Shasta (Cal.) special sheet. (See topographic map of the United States Geological Survey.) Locate Mt. Shasta. What do you find near the summit of Mt. Shasta which you have not seen on any other mountain that we have studied? How are glaciers indicated on the map? How many do you find on Mt. Shasta? On which side of the mountain are the largest ones found? In which direction from the summit is Hotlum glacier? In which direction must its ice be moving? Which part must melt fastest? Is Hotlum widest in the upper, middle, or lower part? How do you think the thickness of the ice in the lower part compares with the thickness in the middle? Give reasons for your answer. What effect must the moving ice have upon the surface of the mountain over which it is moving? What effect does the friction on the sides of the valley have upon the rate of movement of the ice along the sides of the glacier? Note the blue lines which cross the glacier. Which way do they bend in crossing? Which part of the glacier probably moves fastest? What effect will this have upon the texture of the ice?

How many little streams take their rise just below the lower part of Hotlum glacier? Where do you suppose they get their supply of water? What does the area of small brown dots below

Bolam glacier represent? How does the front of Bolam glacier differ in shape from the front of Whitney glacier? Do you know of any ancient glacier which was lobed? When a glacier spreads out at the bottom, as Hotlum glacier does, will the striæ which it makes be parallel or divergent?

"In the United States, outside of Alaska, there are not many mountains sufficiently high to have glaciers upon them. In the Rocky mountains perennial fields of ice and snow are almost unknown except in northern Montana. There are several small glaciers in the high Sierra of California, and in the Cascade range are found many glaciers, some of which are of considerable magnitude. The summits of Rainier, Adams, Hood, and Shasta are practically surrounded by glaciers." Locate Rainier, Adams, and Hood.

EXERCISE XLIX

TOPOGRAPHIC FORMS DUE TO GLACIATION

Refer to the Sun Prairie (Wis.) and adjacent sheets. (See topographic map of the United States Geological Survey.) The Sun Prairie sheet represents a series of glacial hills which are composed of unstratified drift material, sand, and gravel. How high are these hills above the surrounding country? What is their general shape? How wide are they? Are their tops sharp or rounded? "These hills, or drumlins, were made not at the end of the glacier where it melts, but along and under the bed. Some projection of the ground over which it was passing probably checked the current of the ice and made it deposit part of its load." What is the general direction of the trend of the drumlins? What does this indicate as to the direction of the movement of the glacier?

Observe the position of the Sun Prairie quadrangle as shown on the large map.[1] See the large map for answers to the following questions. What is the general trend of the drumlins along

[1] Assembled topographic sheets of the United States Geological Survey, as given on page 170.

the east bank of the Crawfish river, west of Watertown? along Rock river, east and southeast of Watertown? along Ashippum river north of Oconomowoc? These drumlins were formed under the Green Bay lobe of the last great glacier which swept down over the United States, at a point not far from the southern boundary of the lobe. How do you account for the different directions which they take?

Do you find the trend from 5 to 15 miles east and southeast of Oconomowoc to be the same as that north of Ashippum

FIG. 20. Section of a Glacial Moraine in the Rocky Mountains on the Line of the Great Northern Railroad

river? As the great ice sheet moved southward it melted at the southern border. When the melting exceeded the southward movement, the front of the glacier retreated northward. When the melting just equaled the melting of the ice, the front of the glacier remained stationary. One of these pauses on its retreat occurred in the region southeast of Oconomowoc, also in the region shown on the Eagle sheet in Folio 1, and in others to the south and west. From what source do you suppose the material came which makes up these hills southeast of Oconomowoc?

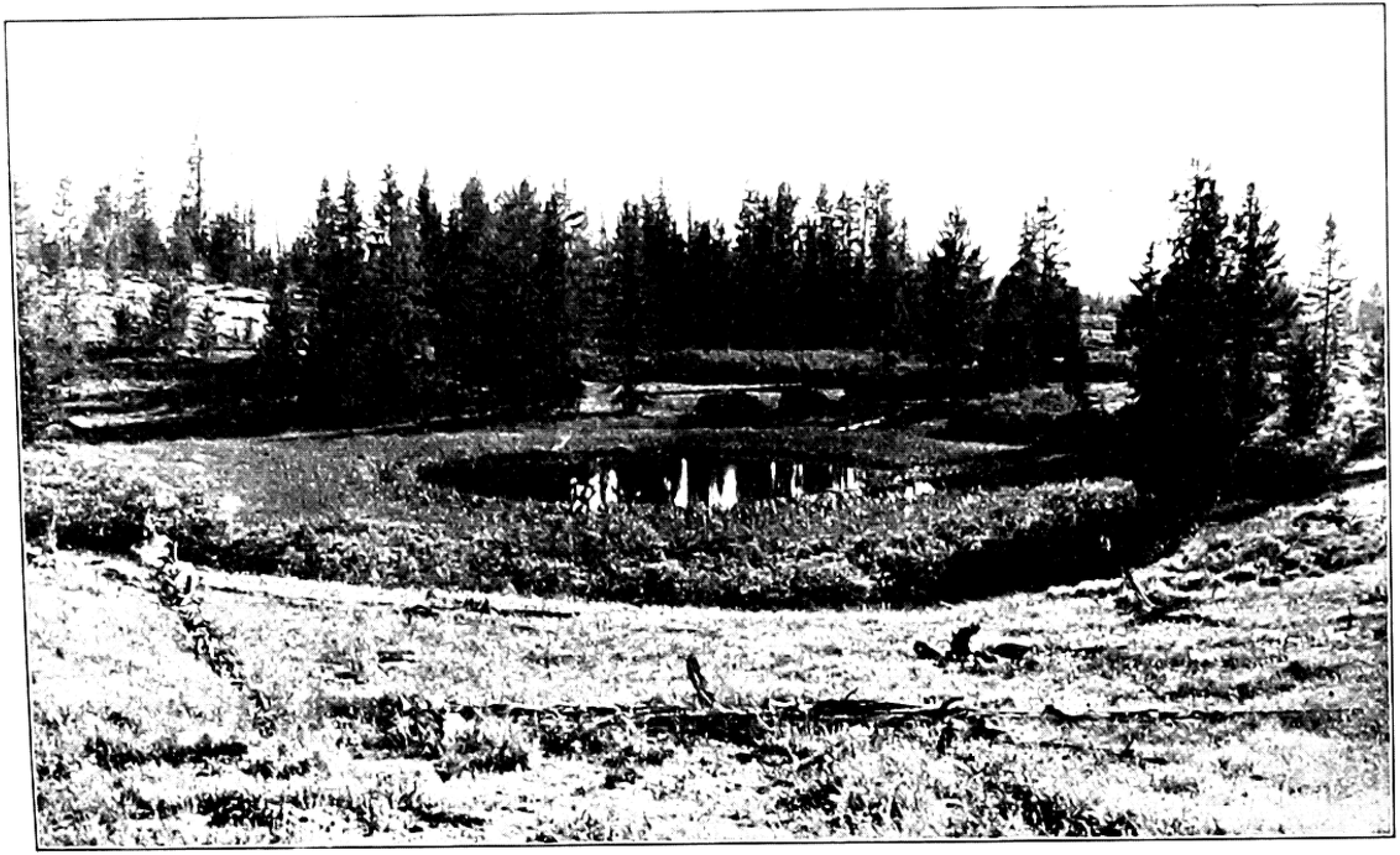

Fig. 21. Belts of Vegetation about a Pond in the Southern Portion of Yellowstone Park

What name is given to such a formation? Why are these hills so irregular? How does this glacial formation differ from drumlins? Do you find any indication of a general trend in the hills represented on the Eagle sheet? If so, what relation does it sustain to the direction of the trend of the nearest drumlins? What angle would you expect the end of a glacier to form with the direction of its movements?

What evidence of youthful drainage do you find? If these streams are young, how do you account for their extreme crookedness in many cases? They are called *consequent streams*. Why?

Fig. 20 shows a section of a glacial moraine. Describe the general shape of the slopes of this hill. Do you find any evidences of stratification? Is stratification characteristic of glacial deposits? Account for this. Observe the bowlders in the foreground at the left. Describe their size and shape. Are they rounded or angular? Account for this. What, besides bowlders, do you find in this glacial deposit?

EXERCISE L

LAKES

Part I

Visit a lake, make careful observations, and, if necessary, seek information from residents of the vicinity.

Is the water level constant throughout the year? Do you note any changes of the average water level from year to year? If so, do you find evidence that it is higher than formerly? What evidence? Do you find evidence that it is lower than formerly? If so, what evidence? Account for any change that may have occurred in the water level. Do you find evidence that the lake is being filled with sediment? If so, what evidence? Is the outlet a vigorous stream? Are its tributaries or its outlet the greater menace to the life of the lake? Of what value to man is this lake?

PART II

Refer to a map of North America and compare the number of lakes in Canada east of the parallel of 100 degrees west longitude with the number of lakes in the southern part of the United States. Refer to a map of the United States and compare the number of lakes east of the Missouri and Mississippi rivers and

FIG. 22. Bear Lake, at an Elevation of 6700 Feet, in San Bernardino Mountains of Southern California

The banks are so steep that the zones of vegetation are not marked

north of the parallel of 40 degrees north latitude with the number of lakes south of this region. How is the great number in one region accounted for?

Lakes have been called the *settling basins* of the rivers. What is there in this name which is appropriate? Considering this alone, which would you think would have clearer waters, the St. Lawrence river or the Missouri? How does this agree with what you know of the clearness of the water of the two rivers?

Of what value to commerce are the Great Lakes?

PART III

Examine Fig. 21. Locate the sedges with reference to the lake. Compare the positions of sedges and shrubs. Which occupy drier ground, the shrubs or the pine trees? The former outlet of the lake can be seen in the background, leading toward the right. What kind of growth now fills it? From this picture, or from other sources of information, arrange the following in the order of their natural places of growth, beginning with the aquatic plants: pine trees, water lilies, willows, sedges, grasses.

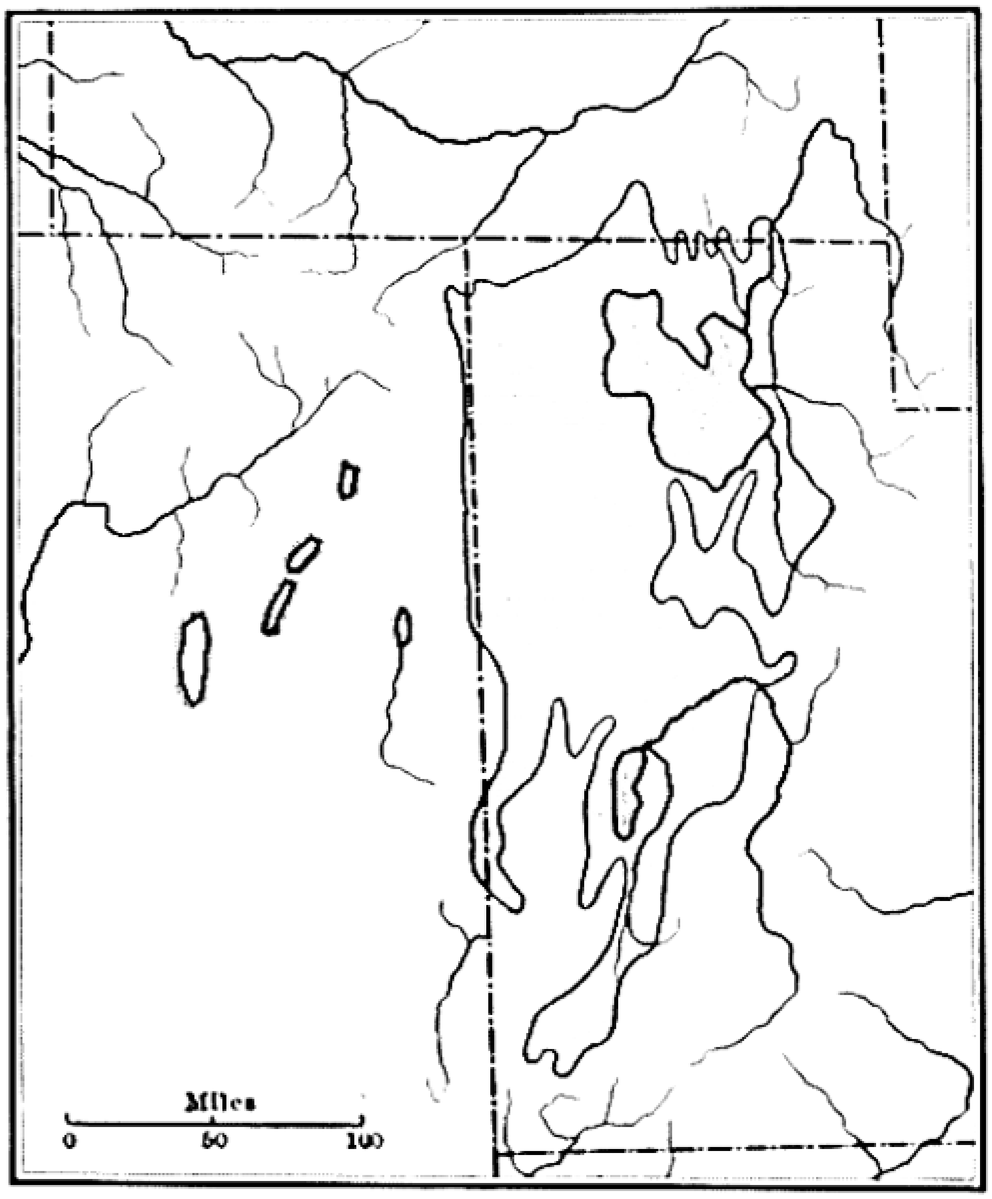

FIG. 23. Map of the Ancient Lake Bonneville with its Modern Representatives, Great Salt Lake and Sevier Lake

PART IV

Refer to the Norfolk (Va.) sheet (see topographic map of the United States Geological Survey), and read the description in Folio 2. What belts of vegetation are found around the margin of the Dismal swamp? Describe the cypress trees by referring to the picture in the folio. According to the author of this folio, which is encroaching on the other, the swamp or the region of vegetation? How is man assisting in this process? To what does the soil of this swamp owe its fertility? How is peat formed? How is peat sometimes used? To what use are men putting Lake Drummond?

EXERCISE LI

EXTINCT LAKES

Refer to the map, Fig. 23. What is the length in miles of Great Salt lake? What was the greatest length of Lake Bonneville, according to this map? Give the evidences, so far as you know them, which go to show that Great Salt lake is a remnant of Lake Bonneville. Was this change in size due to drainage, filling, or evaporation? How do you know? If Lake Bonneville was a fresh-water lake, how do you account for the saltness of Great Salt lake?

According to the map, Fig. 24, how far beyond its present limit did the Gulf of California extend? How far was the mouth of the Colorado river from its present mouth? The delta was built up, thus cutting off the head of the gulf. The river followed one of its distributaries to the lower portion of the gulf. Was the newly made lake salt or fresh? Rainfall is very light in this region, averaging from 2 to 5 inches annually; evaporation is very rapid. Would time make this lake more or less salt?

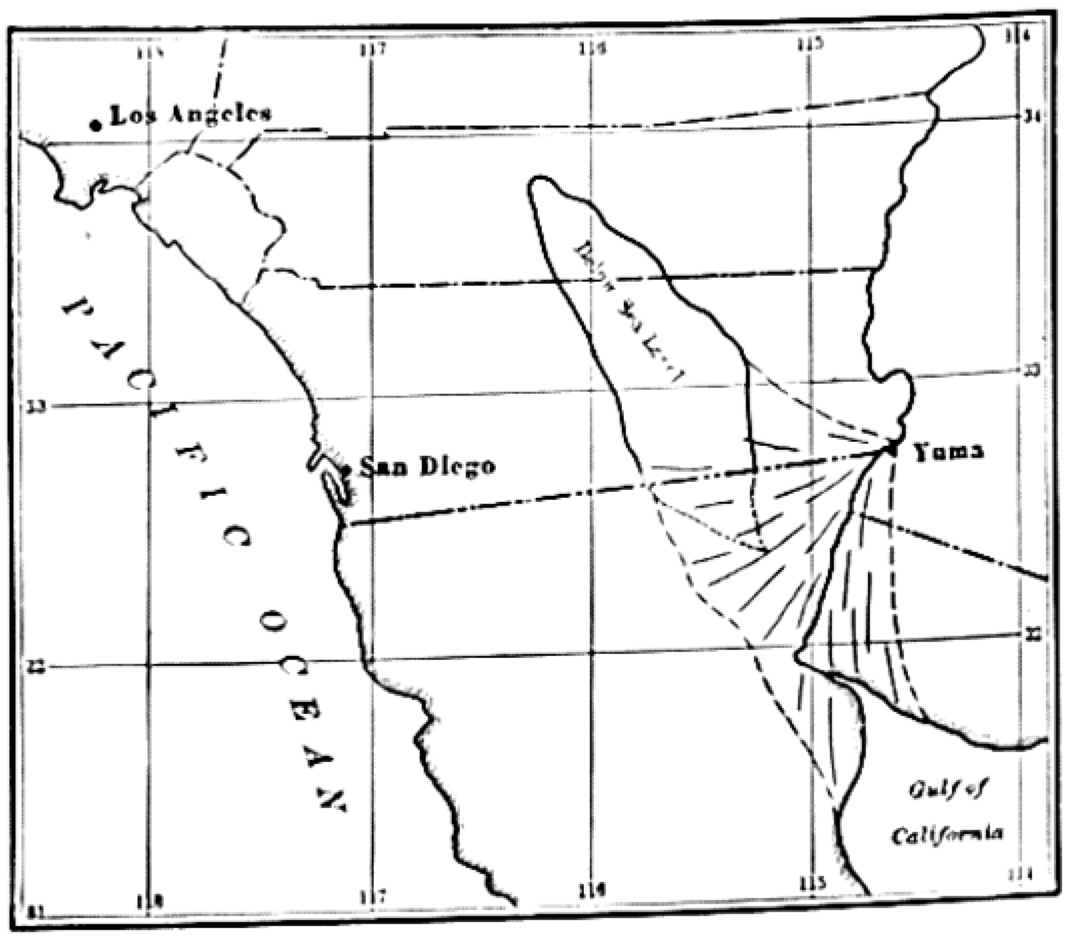

FIG. 24. Map of the Bed of the Ancient Salton Sea, about 300 Feet below Sea Level, showing the Probable Former Extent of the Gulf of California and the Delta of the Colorado River

Except for an occasional overflow of the Colorado river, this region at present is entirely dry. What do you suppose has become of the salt? In what part would it probably be

found in the largest quantities? Do you think this part would make good agricultural land? Why? Some remarkably fertile soil is found near the Mexican boundary line and in the southern portion of this old lake bed. Explain why it is fertile. Water for irrigation is brought from the Colorado river. Does the land slope in the right direction to aid in transporting the water?

Read about Death valley, tell what of economic importance is found there, and account for its presence.

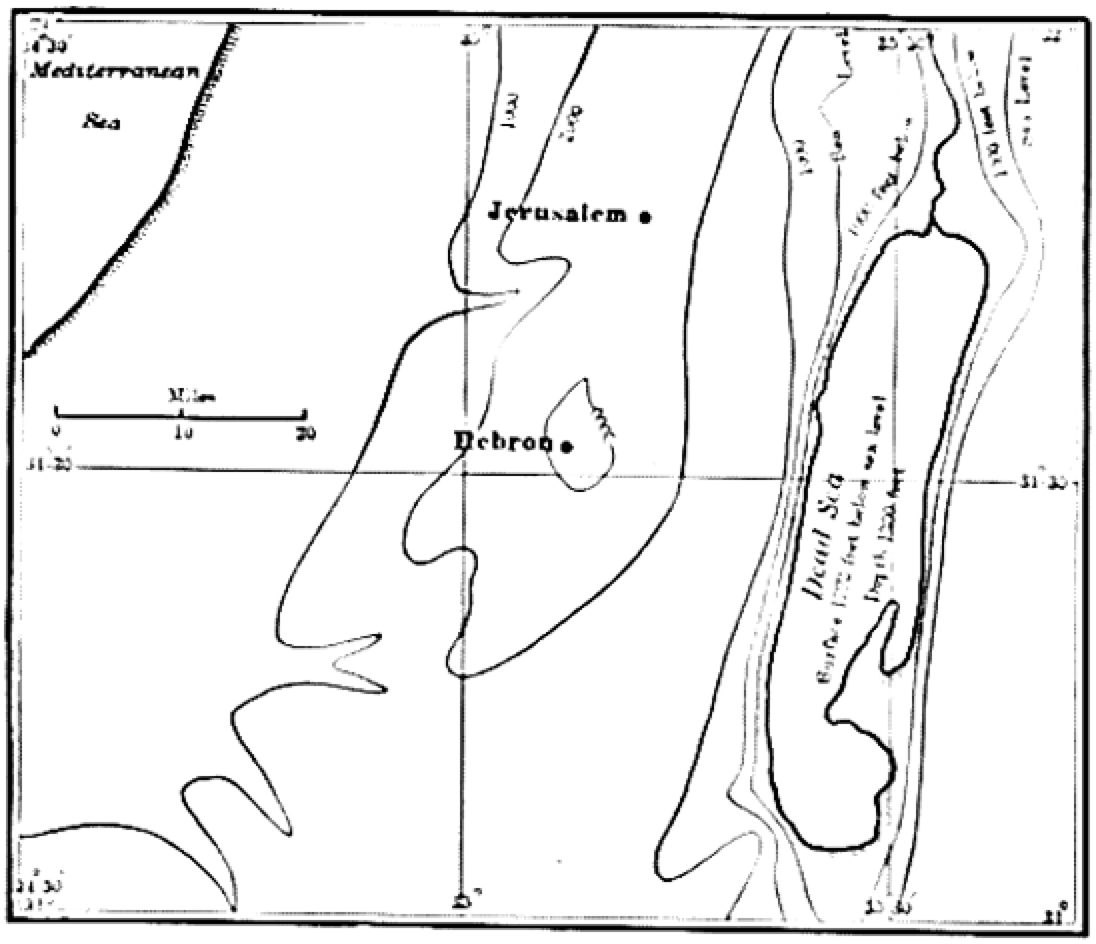

FIG. 25. Contour Map of the Dead Sea, Palestine, Western Asia

Locate the Dead sea. How far below sea level is its present surface? (See Fig. 25.) How deep is the water? If this sea should dry up, how far would its bed be below sea level? How far below the level of Jerusalem?

Note any other extinct lakes that you think worthy of special mention.

EXERCISE LII

SOLIDS IN SOLUTION

Fill a small beaker half full of water. Add a very little powdered alum and stir the mixture. Can you see the alum? What has become of it? It is said to be *in solution;* water is called a *solvent* and alum is said to be *soluble.* Add powdered

alum slowly, stirring all the time. Continue this until the alum no longer dissolves, but settles to the bottom of the beaker. The solution is now said to be *saturated.* Define *saturated solution.* Your beaker now contains a saturated solution, with a little of the undissolved solid as a sediment in the bottom. Put this over the flame of the Bunsen burner and heat it until it boils. What becomes of the sediment? Is cold or hot water capable of holding a larger amount of alum in solution? Make a very strong solution of alum in water and pour it into a beaker with the end of a string hanging down into it, as shown in Fig. 26. Let the beaker stand for a day or two until part of the solution evaporates. Remove the string from the solution. Describe what you see. What effect have cooling and evaporation upon a saturated solution? How could you separate a solid in solution from its solvent?

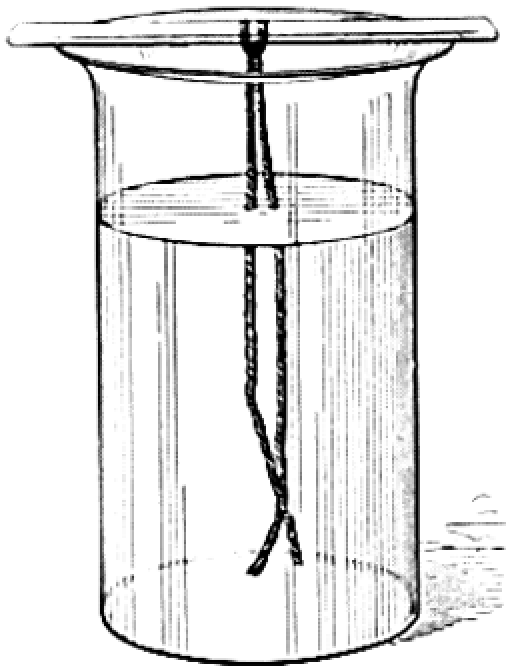

FIG. 26. A Beaker arranged for the Formation of Crystals of Alum

Arrange a piece of apparatus as shown in Fig. 27. Partly fill the bottle with a saturated solution of photographers' hypo (sodium hyposulphite). Set the adjustable pinchcock so that the solution will drop very slowly — not more than two drops per minute. Allow the process to continue for several days. Describe and explain the method of formation of the material which collects on the glass plate below.

Crush to powder some marble in a mortar. Put some of the powder in a small beaker and fill the beaker with water. Let this stand for a day or two. Carefully pour off the water and filter it. Boil the filtered water in an evaporating dish, evaporating it to dryness. Do you find any residue in the evaporating dish? Is marble soluble in water? Put some of the powdered marble in a small beaker and fill the beaker with water. Lead a tube from a carbon dioxide generator into this beaker of water and let the gas slowly bubble up through

the water. Continue this process for a day or two. Again pour off the water, filter, and evaporate to dryness. Do you find any residue in the evaporating dish? Is marble soluble in water which has carbon dioxide in it? Water with carbon dioxide is responsible for the removal of most of the material in the making of caverns in limestone.

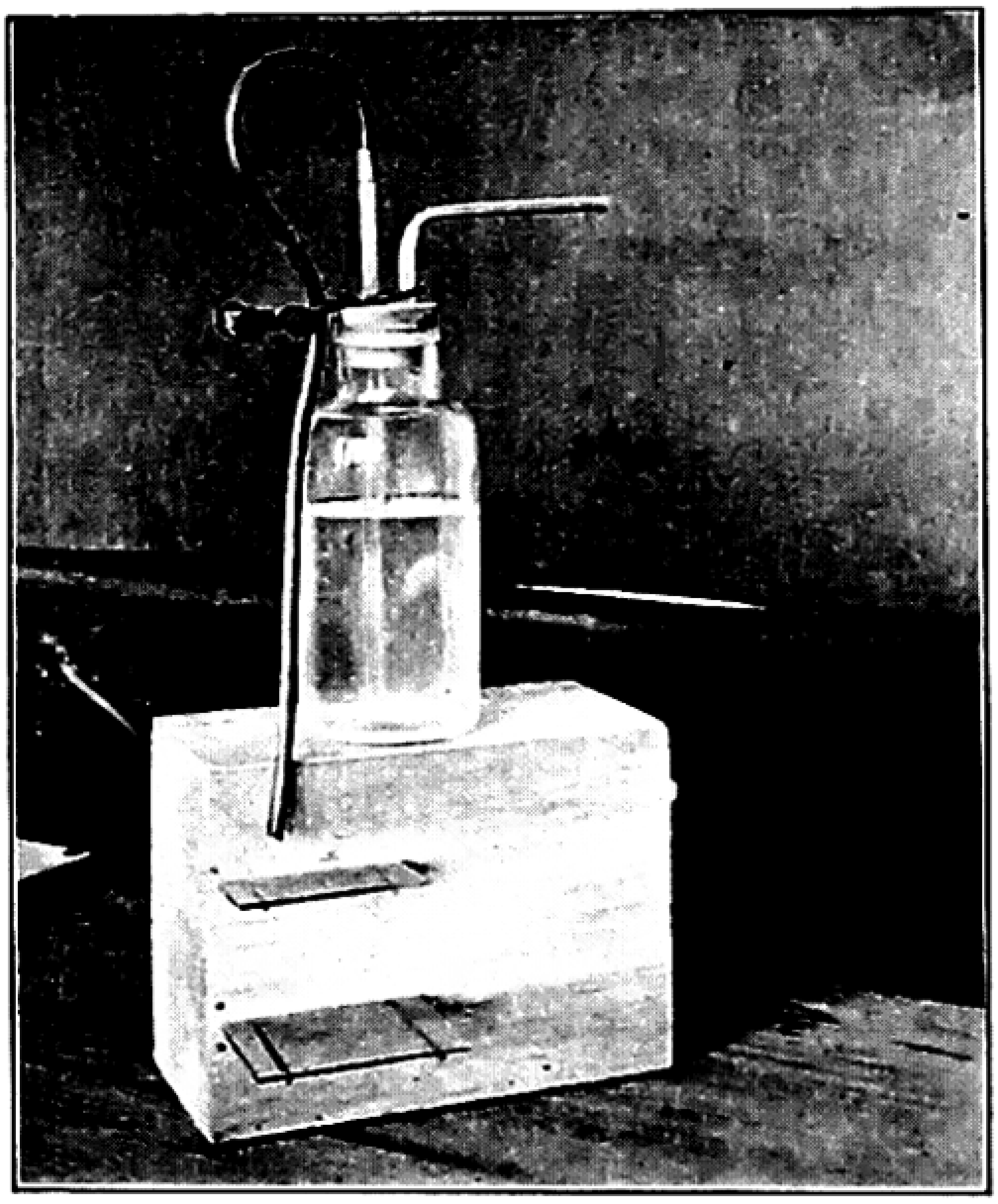

Fig. 27. A Bottle and Siphon arranged for the Formation of Stalactites

Blow into the open tube until the solution flows from the siphon, and then adjust the pinchcock

Examine a stalactite. Describe shape, structure, color, and anything else worthy of note. Apply a small drop of hydrochloric acid to the stalactite and describe the result. Effervescence is a proof that it has lime in its composition. Describe the process of the formation of a stalactite. If possible, visit a cavern and describe what you see. Illustrate by drawings or photographs.

EXERCISE LIII

VEINS

How are rocks fractured? (See Exercise XXXI; also Topic 35, Causes of Mountains, p. 16, and Topic 62, Earthquakes, p. 27.) How deep into the earth do cracks and fissures extend? Underground water may follow these fissures wherever they

go. As water descends to great depths what change of temperature does it undergo? What effect does this change of temperature have upon its ability to dissolve rocks? (See Exercise LII.) If water is thoroughly saturated with material in solution, what effect will be produced by cooling it? This is the process by which cracks and fissures in the rocks are filled. What materials may be dissolved by water? Why are veins of interest to the miner? Distinguish between the manner of formation of veins and dikes. (See Topic 61, Volcanic Phenomena, p. 26.)

Examine veins in a cliff or in specimens which you have in the laboratory. What kind of material do you find in the rock

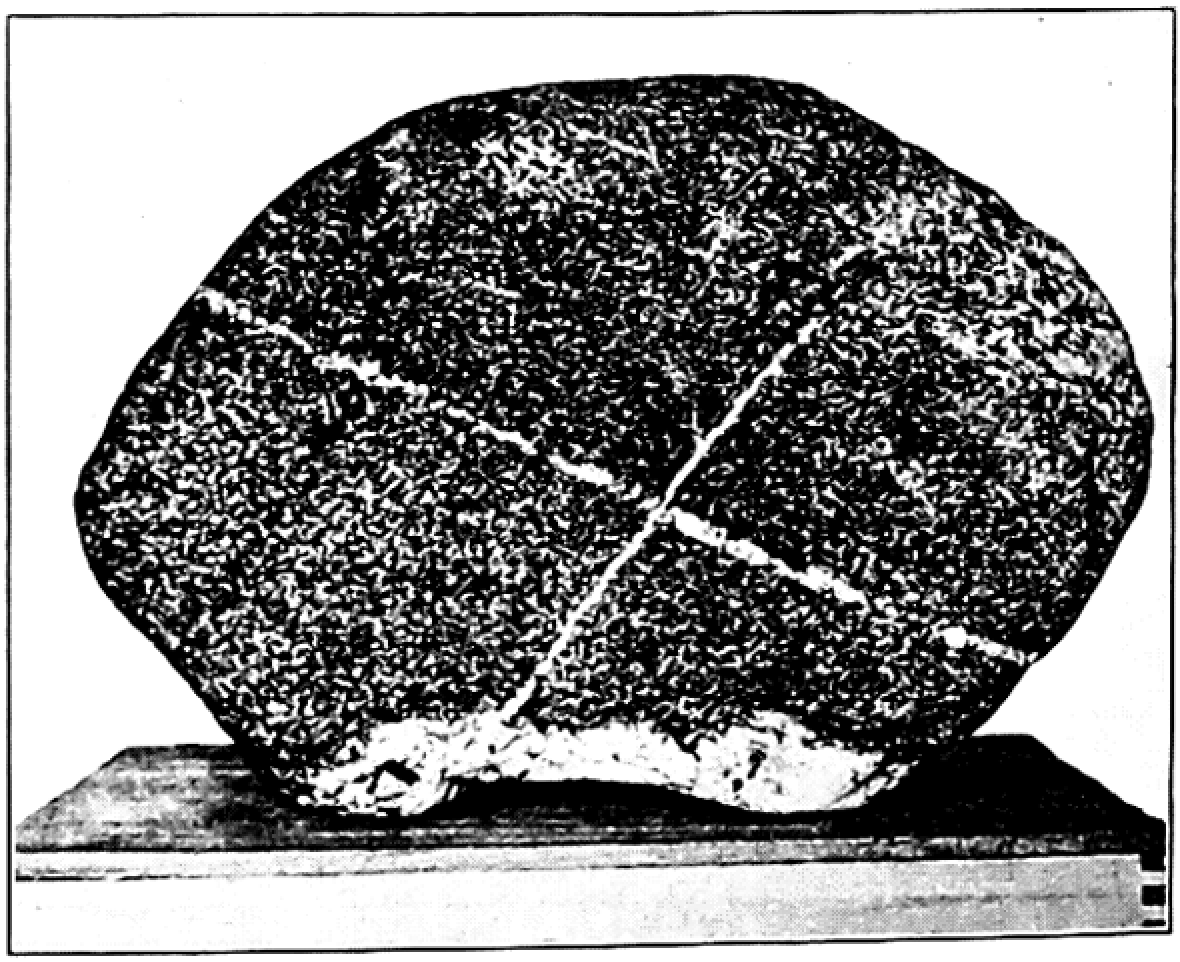

FIG. 28. A Rock with Intersecting Veins

which contains the veins? Of what kind of material are the veins composed? Which is harder, the veins or the rock in which they occur? Which will wear away faster when subjected to the action of the weather? Give the width of the widest vein which you find; of the narrowest. Are the veins which you find in any one cliff of equal age? Give reason for your answer.

Illustrate by drawings what you see, showing as many facts as possible about veins.

EXERCISE LIV

DENSITY AND TEMPERATURE OF SEA WATER

PART I

Weigh accurately about 100 grams of sea water. Boil and evaporate to dryness. Weigh the residue and calculate the percentage of solid matter. From the books determine what part of the solid matter is common salt (chloride of sodium). According to this, how much common salt in 100 pounds of sea water?

PART II

DATE	TEMPERATURE		DENSITY	
	Bay	Ocean	Bay	Ocean
July	77	68	1.0238	1.0228
January	58.5	60	1.0245	1.0230

The accompanying table gives the temperature and density of the water in San Diego bay and in the open sea for July and January. In which is the water warmer during the month of July? Account for this. In which is it warmer in January? Account for this. In which is the temperature more nearly uniform throughout the year? According to this table, is the water denser in the bay or in the ocean? The density of the water in the Red sea and in the Mediterranean sea is said to be from 1.027 to 1.028. Account for this great density.

PART III

According to the table in Part II, is the water denser when it is warm or when it is cold? Which has greater density, water or ice? How do you know? (See Exercise XXXI.) Suppose ice should sink upon freezing. How would this affect its rate of melting under the influence of the sun? How might this affect the climate of a region near a large lake of fresh water?

EXERCISE LV

TIDES

Refer to the United States tide tables, select some port, and note the times and heights of tides for a period of one month or more. In what units are the heights of tides given? From what is the height of a tide reckoned?

Use cross-section paper. Draw a line lengthwise through the center of the sheet to represent mean lower low water. Use vertical distances to represent the heights of the tides, scale 1 centimeter to 1 foot. Use horizontal distances to represent time, scale 1 millimeter to 6 hours. Use lead pencil and place a dot at the proper point to represent the time and height of each of the four tides for the first day of your observations. Use ink and connect these points consecutively, making a straight line from each to the one immediately following. Do the same for the following day and proceed in a similar manner with all data for the time of observation.

How far in feet is mean lower low water below mean sea level? (See the note at the bottom of the page in the tide table.) Draw a line to represent mean sea level. By referring to the almanac determine the dates of the moon's phases during the time of observations of the tides. On the horizontal line just above the highest high tide make drawings to represent these different phases of the moon, being careful to get them in the spaces for the correct dates. Give your diagram a title.

At what phase of the moon are the tides highest? At what phase are they lowest? At what phase do the tides have greatest range? What name is given to these tides? At what phase of the moon do the tides have least range? What name is given to these tides? Make drawings to show the positions of the earth, the sun, and the moon at the time of greatest range of tides; at the time of least range of tides. What causes tides? How do you know?

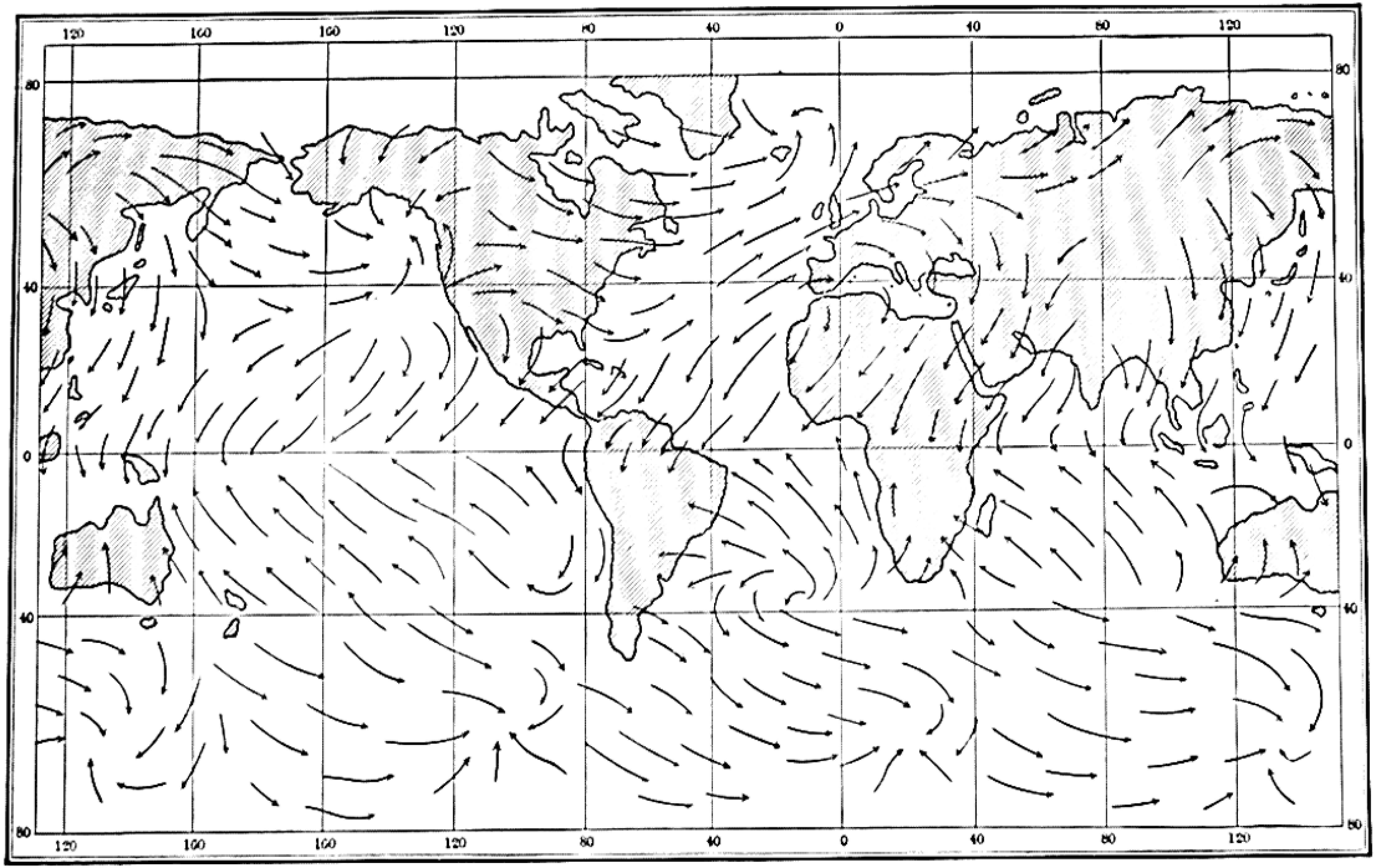

FIG. 29. Winds of the World for January

EXERCISE LVI

OCEAN CURRENTS

Observe the pilot chart of the North Atlantic ocean. How is the direction of the ocean currents indicated? (See the explanation near the lower left-hand corner of the map.) What is the direction of the current at each of the following points: (1) southwest of the Cape Verde islands, 16 degrees north, 25 degrees west? (2) on the equator off the east coast of South America? (3) from 10 to 20 degrees north latitude in the Pacific ocean? Compare these directions with the directions of the prevailing winds at these points, as given by the pilot charts. Compare the courses of the ocean currents of the world with the directions of the prevailing winds, as shown by the maps, Fig. 29 and Fig. 30. What do the books give as the cause of ocean currents?

What is the direction of the current in the Caribbean sea? in the Atlantic ocean between Florida and the Bahamas? What name is given to this current? What is the direction of this current in the Atlantic ocean at a point 40 degrees north and 50 degrees west? Trace this current still further and describe its general shape east of this point. What is the direction of the current off the east coast of Labrador and Newfoundland? Trace this current along the coast as far as you can. Is it a warm or a cold current? What effect does it have on the temperature of the east coast of the United States? What finally becomes of this current? Trace with a pointer the main currents of the North Pacific ocean. Describe their general shape. See the small black figures giving knots per hour, and give the velocity of the current in the region of northeast trades, 130 degrees west; in mid-ocean south of the Aleutian islands; off the west coast of Oregon.

Do you find indications in the Pacific ocean of a cold current from the Arctic regions? What do you know of the temperature of Vladivostok? (See Fig. 4.) Compare its temperature in winter with that of Portland, Oregon. Compare the latitude of these two places.

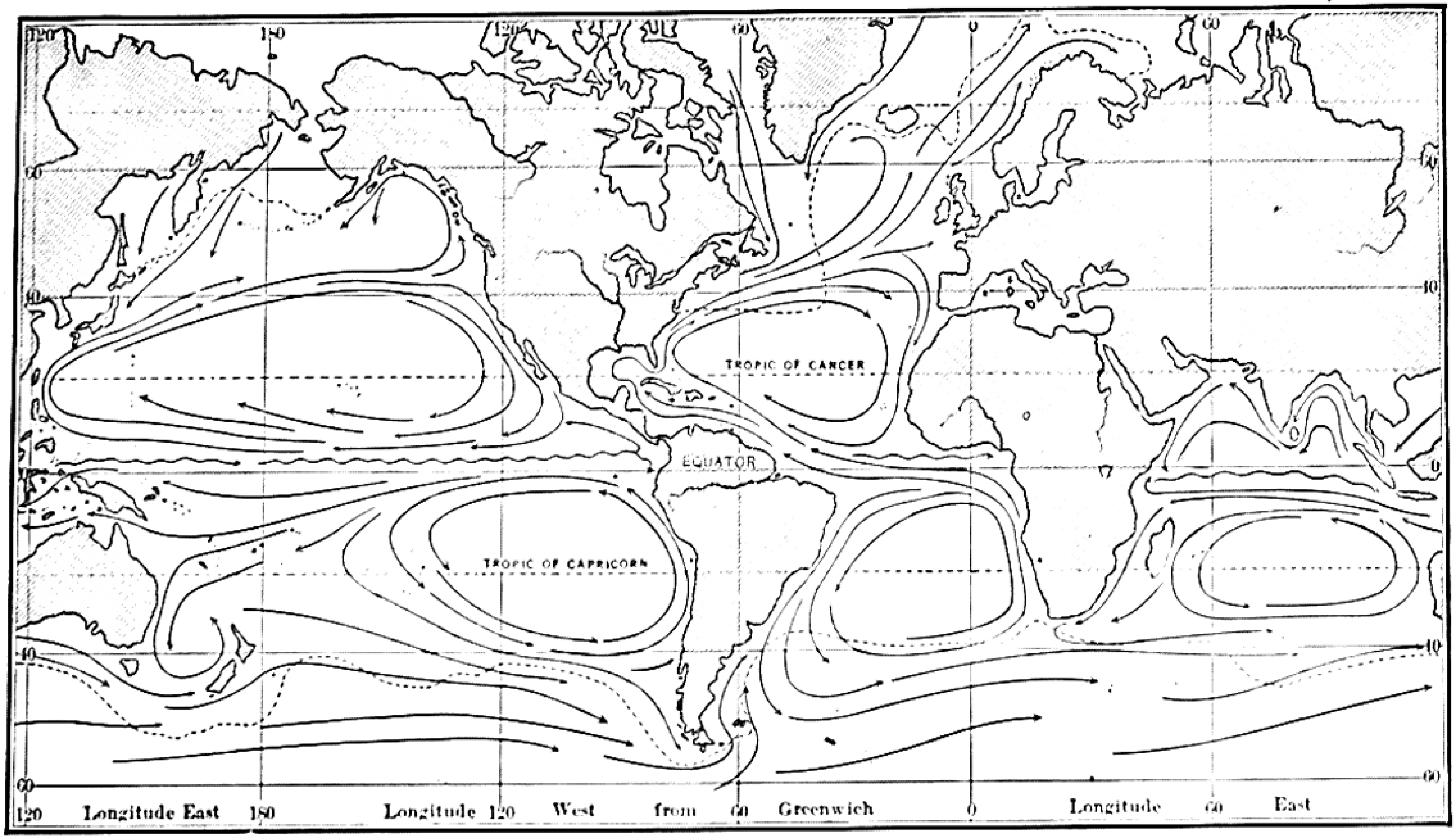

Fig. 30. Chart of Ocean Currents

Broken lines show limits of floating ice

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EXERCISE LVII

ICEBERGS

Put a piece of ice in a vessel of cold water. Why does it float? Which is heavier, a cubic foot of ice or a cubic foot of water? Define *density*. Which has the greater density, ice or water?

Push the ice down so that it is entirely under water. Does it resist your pressure? The force that tends to lift it up is called the *buoyant force of water*. Suppose that a glacier is passing down a slope into the sea, so that the lower part is immersed in water. What force is thrusting it down into the sea? What force is tending to lift it up? Explain how icebergs are formed from such a glacier.

About what proportion of the floating ice is under water? Does it float with the broadest surface up or down? Turn it over and see if you can make it float in another position. In how many positions can you make it float? Suppose one side should melt away. What effect would this probably have upon the position of the ice in the water? Account for an iceberg's turning over in the sea.

To find what proportion of a floating object is beneath the surface, divide its specific gravity by the specific gravity of the liquid. Dryer (*Lessons in Physical Geography*, p. 255) gives the specific gravity of sea water as from 1.024 to 1.03, when at the temperature of 60 degrees. The specific gravity of sea ice is also given as .9175. Using the specific gravity first given for sea water, calculate what proportion of an iceberg is under water. Do the same, using the second specific gravity which is given above. What proportion is above water in each case? Why should more than one specific gravity be given for sea water?

Where do most of the icebergs of the North Atlantic ocean originate? What is the fate of those that float south? How far south do they ever go? Describe the location of the line marking the limit of floating ice in the North Atlantic. (See Fig. 30.) What is the principal danger to ships cruising among icebergs?

EXERCISE LVIII

THE SEA AND MAN

Part I

Use a globe and string; place the string on the surface of the globe so as to connect with the shortest line the Galapagos islands and the island of Borneo. In which direction does this line extend? With what important mathematical line on the earth's surface does it almost coincide? If your string were extended so as to make a complete circle round the earth, would it make a great or a small circle?

San Francisco and Yokohama are in almost the same latitude. Connect these points on the globe with a string in such a way as to make the shortest line between them. In what direction does the line pass? Near what points on the earth's surface does it pass? If this line were extended so as to make a complete circle round the earth, would it make a great or a small circle? Does this circle coincide with any circle of latitude? Compare this shortest line which you have drawn between San Francisco and Yokohama with the route actually taken by steamships plying between these two ports, as shown on the pilot chart of the North Pacific ocean. How would you find the shortest line between any two points on the earth's surface?

Part II

Heat equal weights of water and rock to the same temperature. Place them aside and allow them to cool. Which cools more quickly? Cool equal weights of water and rock to a low temperature and place them in the direct sunlight. Which heats more quickly? Which gets hotter in summer, land or water? Which is more nearly uniform in temperature throughout the year? What effect does this fact have upon the climate of places near the sea or near a large lake?

Fig. 31. Avalon Bay, Santa Catalina Island, Southern California

Part III

Slowly boil a flask of sea water and condense the steam by passing it through a tube inclosed in a jacket of cold water. Taste the condensed vapor. Do you find salt in it? Ocean steamships are so equipped that they can supply drinking water

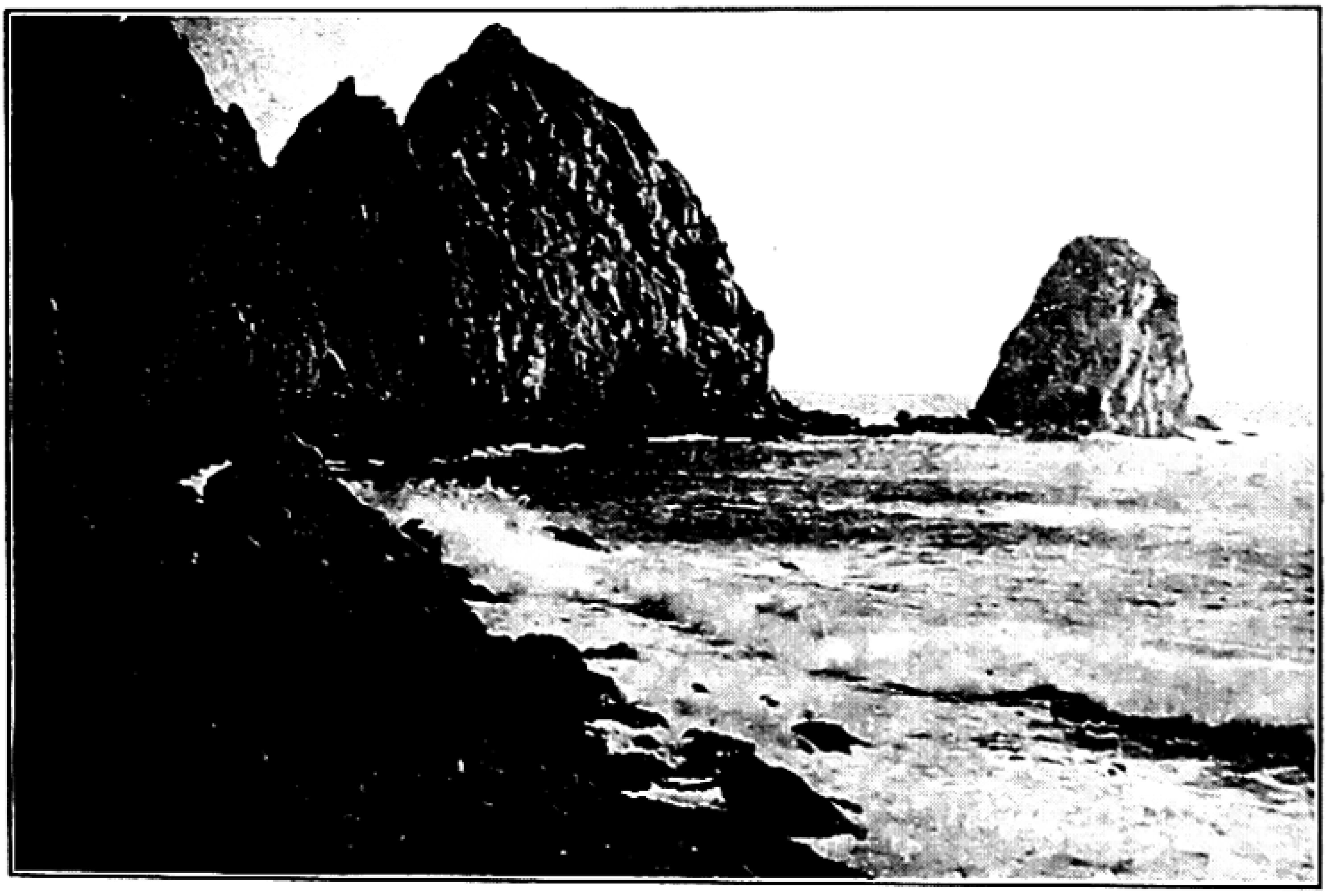

Fig. 32. The Rocky Headland shown in the Distance in Fig. 31

The detached rock island is called Sugar Loaf

from sea water by distillation. Is water vapor which rises from the sea salt or fresh? If rain water were salt, how would vegetation be affected? How does evaporation affect the density of the water in the sea? Name some bodies of water in which this is specially noticeable.

Part IV

Make a list of food products which are obtained from the sea. Make a list of other useful articles which are obtained from the sea.

EXERCISE LIX

HEADLANDS, BEACHES, SEA CAVES

Fig. 31 is a picture of Avalon bay, Santa Catalina island, southern California. Fig. 32 is a detail of the same, showing the rocky headland at one side of the bay. Observe the bowlders lying in the foreground. Describe shape and size. What effect will action of the waves have upon the shape and size of these

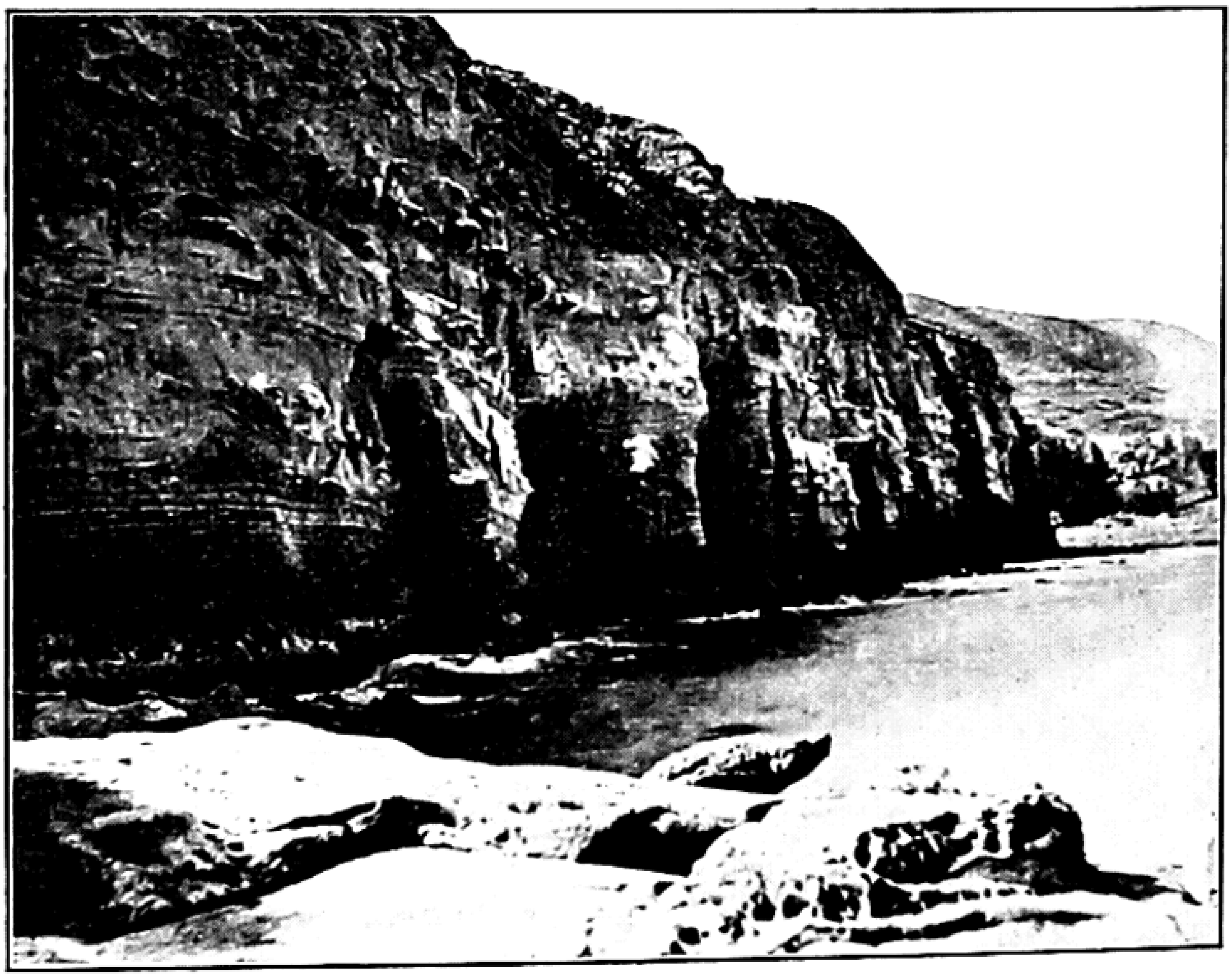

FIG. 33. Sea Caves at La Jolla (pronounced *la-ho-yah*), Coast of Southern California

The cliff is sandstone

bowlders? How will the waves accomplish this? Compare these bowlders with those shown in Fig. 38 and account for the difference. What will finally be the fate of any bowlders constantly subjected to the action of the waves? After the advance of a wave its waters return to the sea, bearing some rock waste with them. Rock waste of what sizes can be carried most readily

by the waves? What disposition will the sea make of material thus removed from the shore?

What agencies probably removed from the cliff the bowlders shown in Fig. 32? In times of storm the waves have sufficient force to pick up bowlders and bear them along, thus hurling them against the cliff. Which would probably prove the more destructive agent, waves alone or waves armed with bowlders, pebbles, and sand? Observe the rock island, Sugar Loaf. It has been detached from the mainland by the attack of the sea. Predict the effects which the sea will yet produce upon the mainland. Fig. 33 shows a sandstone cliff at La Jolla on the coast of southern California. Describe the effects which the waves have produced here. Why has their attack been more effective in some parts of the cliff than in others? Sometimes fantastic forms result from the action of waves. Tell what you see in Fig. 34. What structure of the rocks makes this arch possible?

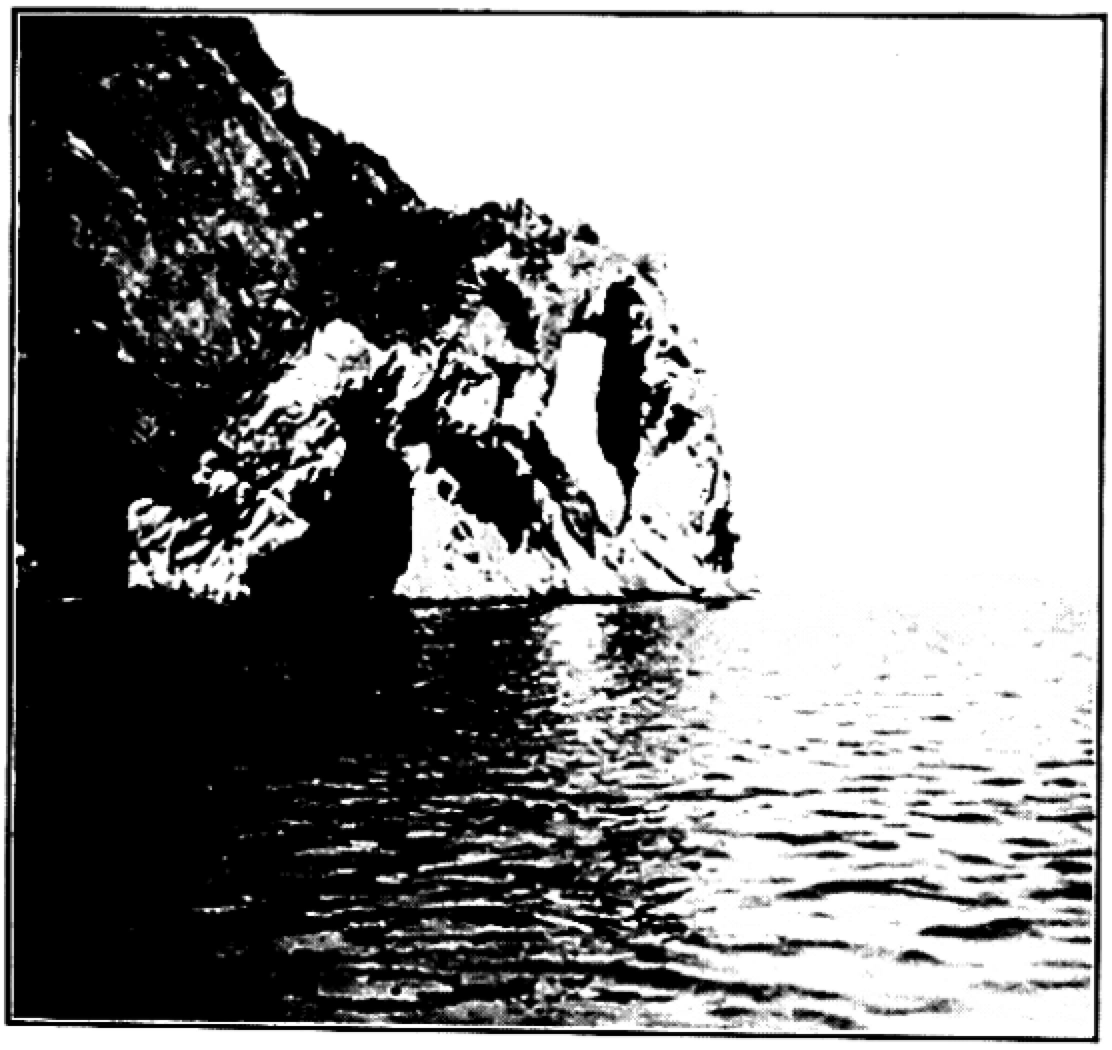

Fig. 34. An Arch cut by Waves

What condition of sea bottom is necessary to produce breakers? (See Topic 82, Waves, p. 35.) Judging from the fact that but one breaker appears on the shore in Fig. 32, would you think the sea is deep or shallow? Is this characteristic of strong or weak coasts? Which part of the bay in Fig. 31 has the strongest coast? Which the weakest? This bay is what the

books sometimes call a *pocket beach.* What can you see that is appropriate in this name? It is sometimes called a *crescent beach.* Is this name equally appropriate? What difference would you expect to find in the size and the shape of the rock waste at the headland and midway between the two headlands?

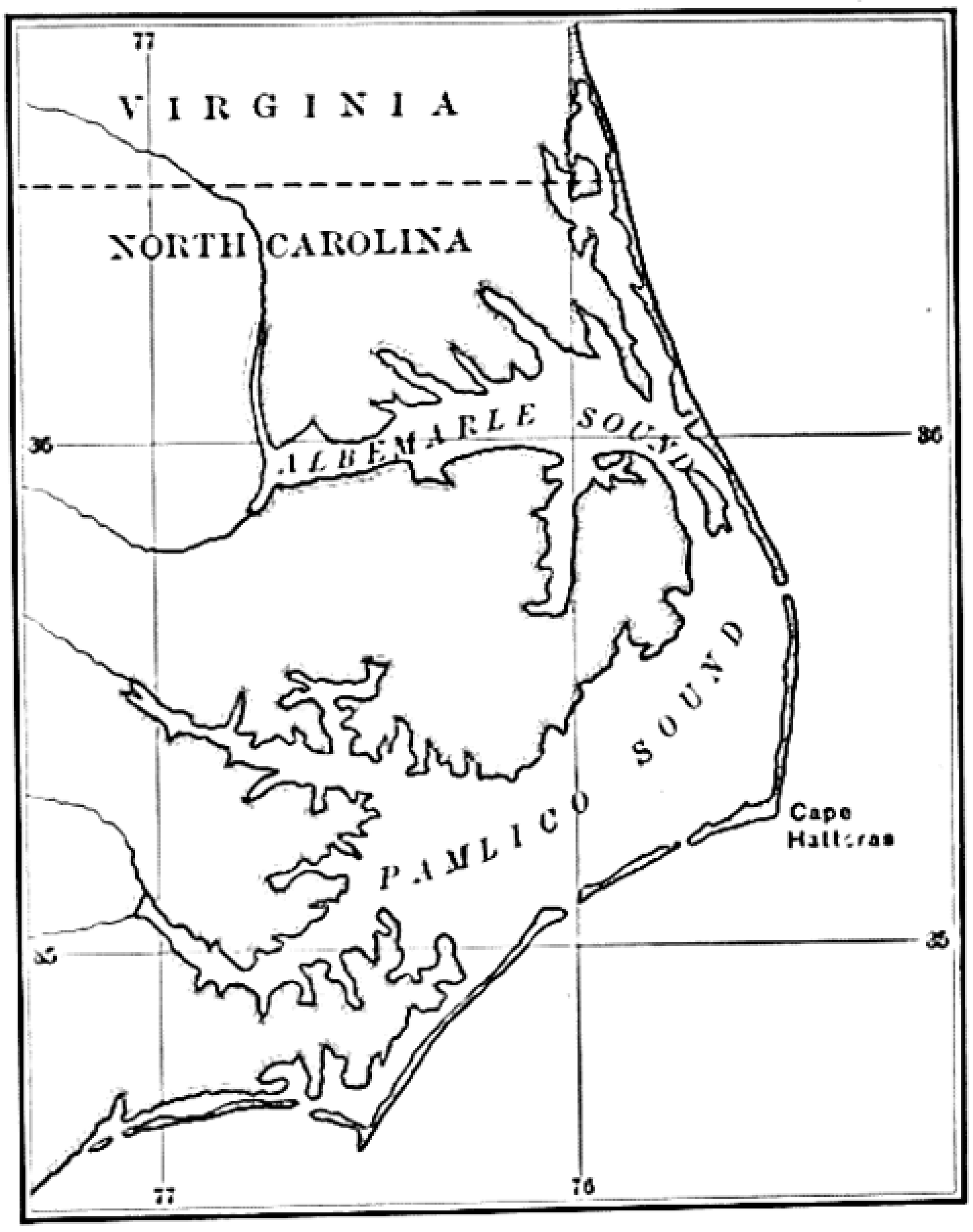

FIG. 35. Map of Sand Reefs off the Coast of North Carolina

If possible visit the coast. Observe sea cliffs, headlands, bowlders, pebbles, sand, beaches, sea caves, bars, spits, marshes, seaweed, and other life along the shore, and anything else that you consider worthy of note. Make a map of the region which you have visited and let your description be as full as possible. Illustrate with photographs or drawings whenever possible.

EXERCISE LX

BARRIER BEACHES

Locate Atlantic City on a map of the United States. How far and in what direction is it from New York city? Refer to the Atlantic City (N.J.) sheet. (Topographic map of the United States Geological Survey.) How much of the region shown on this sheet is mainland? How high is it above sea level? Describe the barrier beaches, giving their distance from the

mainland, direction of trend with reference to the mainland, height above sea level, width, and general shape. Compare them, in all respects named above, with the barrier beaches and bars represented on the map of the Atlantic coast from Beach Haven to Sandy Hook. (See the large map.[1]) Also make a comparison of these beaches and the bars or reefs represented on the maps of the coasts of North Carolina and southwestern Texas. (See Figs. 35 and 36.)

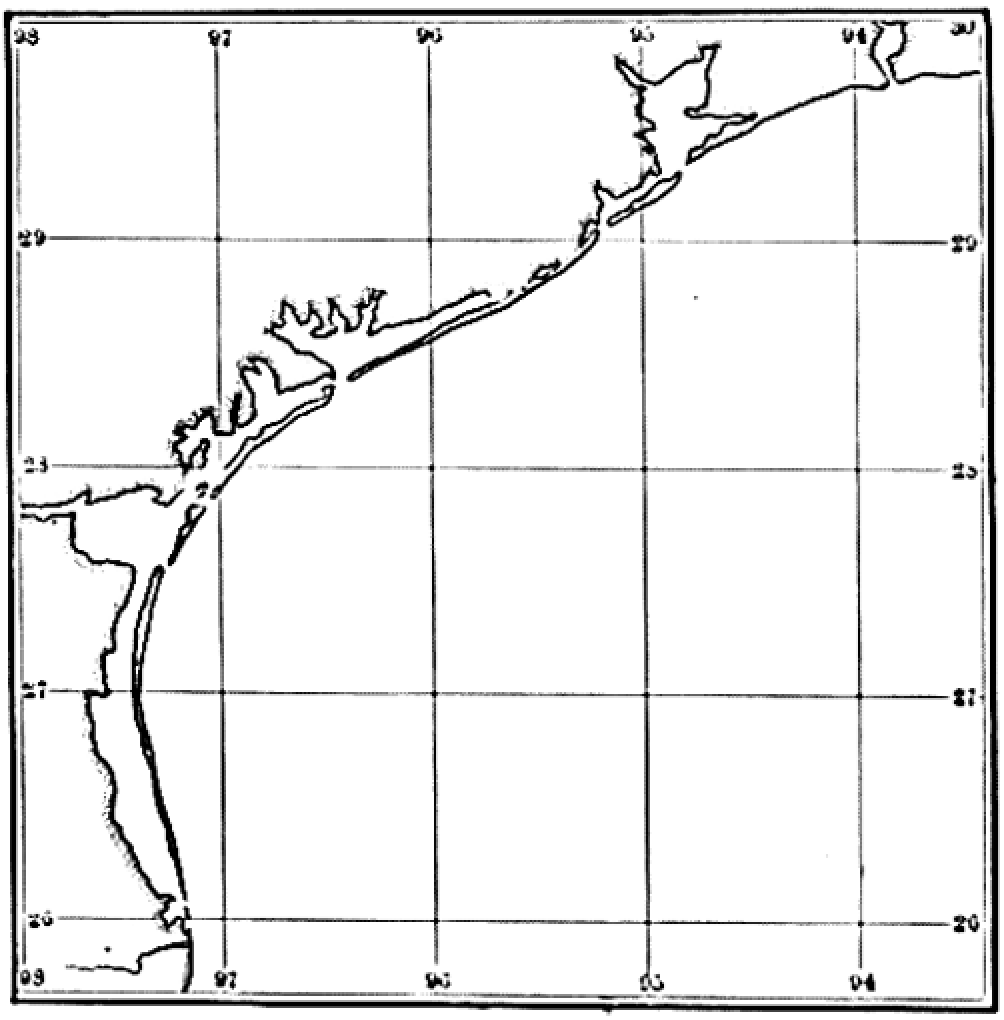

Fig. 36. Sand Reefs off the Coast of Texas

How does the land lie between Atlantic City and the mainland? Describe the position of bays, channels, and "thorofares." Are these bodies of water becoming deeper or shallower? Give reason for your answer. What will finally be their fate? What prevents the inlets from becoming filled with sand? (Read the description in Folio 1.) How is it possible to build railroads across this region? For what is Atlantic City famous? In what respects is it well located? Do you think of any disadvantages due to its location?

Almost the entire region around Provincetown (Mass.) has been built up by the sea. (See the large map.[1]) What do you think is the character of the soil? What evidence of the existence of dunes do you find on this map? What is done to check the migration of dunes? (See the government reports.) What use have men made of the peculiar shape of the coast line at

[1] Assembled topographic sheets of the United States Geological Survey, as shown on p. 170.

Provincetown? Do you think good harbors could be made on the east side of Cape Cod peninsula? Give reason for your answer.

EXERCISE LXI

DROWNED AND ELEVATED COASTS

Refer to the Boothbay (Maine) sheet. (See topographic map of the United States Geological Survey.) This sheet represents a *drowned coast*. What does this mean? Describe the shape of the inlets and the projecting lands. Measure the length of the coast in a straight line from Griffith Head to Pemaquid Point.

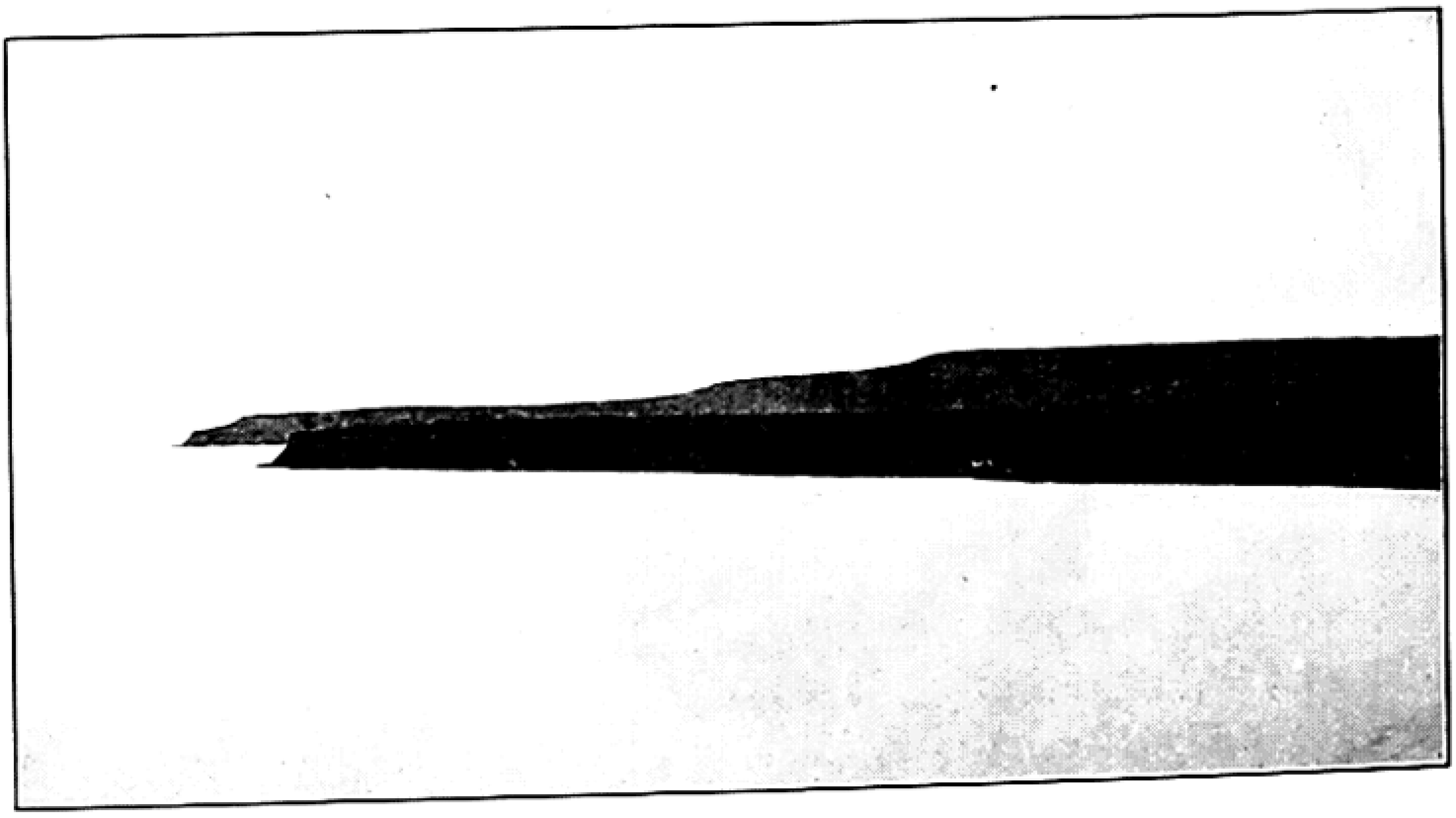

FIG. 37. Terraces cut by the Sea at Point San Pedro, California, showing a Rising Coast

Estimate the length of coast line between these two points, passing around the bays but not entering the broad rivers. Characterize this coast line as *straight* or *crooked*. What land forms would result if Linekin neck should sink 100 feet? Are islands common on drowned coasts? What is the shape of the islands represented on this map? of the hills? Is there a general trend of the land forms? If so, in what direction? How is this accounted for? (See p. 4 of Folio 1.)

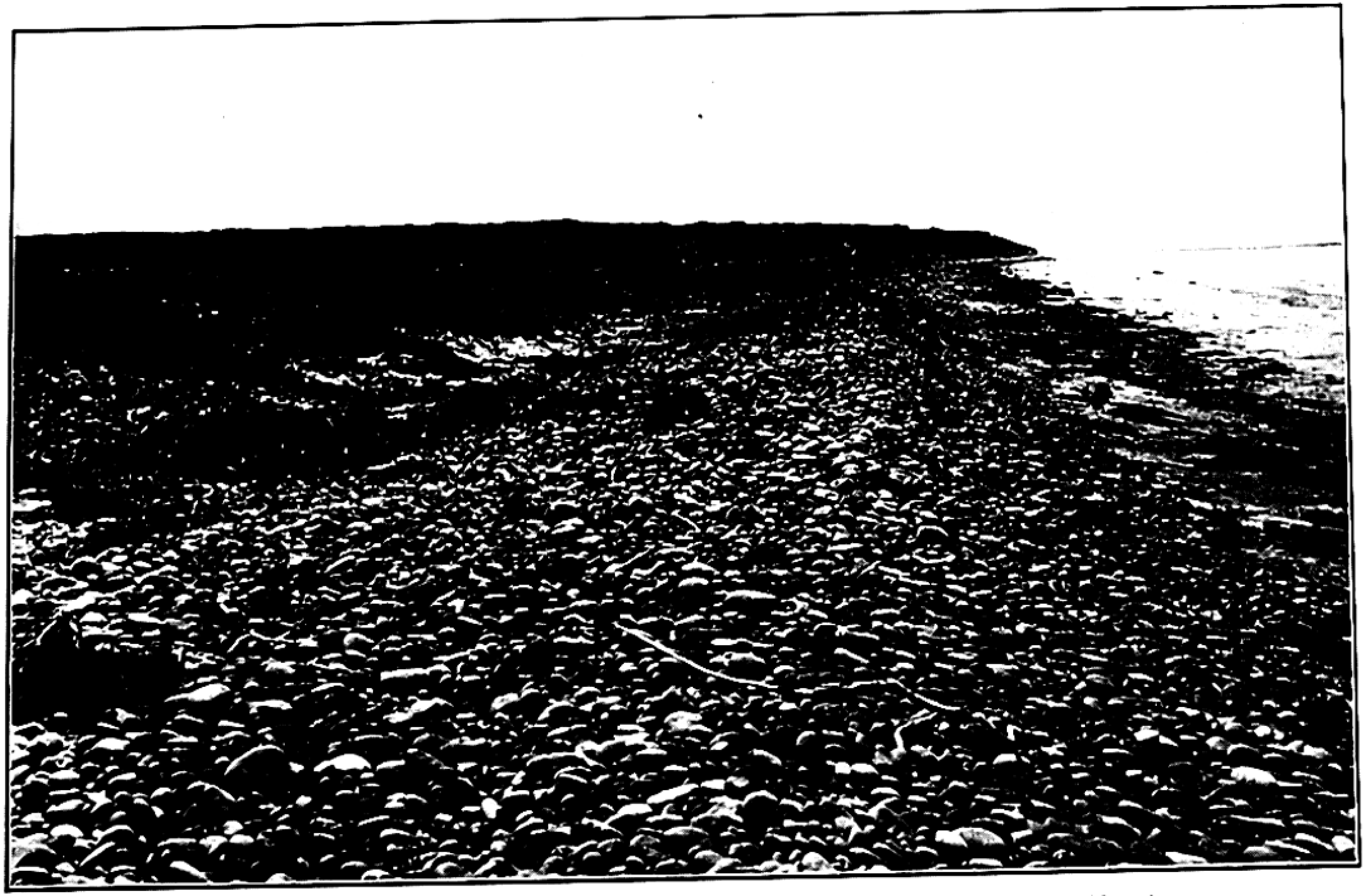

FIG. 38. A Double Pebbly Beach across a Lagoon south of Oceanside, California

The upper beach is not now reached by the waves, probably because of a recent uplift of the coast

Has this region known more of erosion or more of deposition recently? Why was the surface eroded more deeply in some places than in others? Are the rocks now composing the ridges probably hard or soft? Give reason for your answer. Why is it appropriate to call this a "stern and rock-bound coast"?

It is said that a former channel of the Hudson river can be traced through New York bay several miles out into the ocean. What does this indicate as to the movement of the land at New York? Name another river on the Atlantic coast that has been drowned. Do drowned coasts always produce fiords? When do they not? Of what use to men are fiords and drowned rivers? Name two notable examples of drowned rivers on the Pacific coast. What has been the movement of the land along the coast of southern California? (See Figs. 37 and 38.) Describe what you see in Fig. 38. How many elevated beaches or former shore lines can you count in Fig. 37? Compare the shape of the coast line from San Diego to San Pedro (Cal.) with that of the coast of Maine. How do rising coasts usually differ from sinking coasts?

EXERCISE LXII

HARBORS

Compare the number of natural harbors on the Atlantic coast of the United States north of Virginia with the number from Virginia to Florida. Account for the difference in number. How has the number of good harbors affected the growth of cities in the two regions?

What natural features have been utilized to form a harbor at New York (see map if necessary)? at Philadelphia? at Boston? at New Orleans? at San Francisco? at Seattle and Tacoma? at Manila? at Liverpool? Do you know of other natural features which make good harbors?

Do you know of a port with an artificial harbor? What are some of the methods used in building artificial harbors? Define *breakwater*; *dredge*.

EXERCISE LXIII

ECONOMIC MINERALS AND ORES

The *streak* of a mineral is the color of its powder.

Some minerals are much harder than others. A series of ten has been selected, running from the softest to the hardest. This is called the scale of hardness. The hardness of rocks is usually given by number. Following is the scale:

1. Talc. Very soft, can be scratched easily with the finger nail.
2. Gypsum. Can be scratched with the finger nail, but not as easily as talc.
3. Calcite. Cannot be scratched with the finger nail. Easily scratched with the point of a knife.
4. Fluorite. Scratched with a knife, but not easily.
5. Apatite. Not so easily scratched.
6. Orthoclase. Can be scratched with difficulty with a knife blade. It will scratch glass.
7. Quartz. Cannot be scratched with a knife. It will scratch glass.
8. Topaz. Cannot be scratched by quartz.
9. Corundum. Harder than topaz.
10. Diamond. The hardest mineral.

Examine each of the following minerals: pyrite, magnetite, hematite, limonite, cuprite, chalcopyrite, malachite, azurite, galenite (lead), gold, gypsum, asbestos, halite (salt), calcite. (The first four are forms of iron. The second four are forms of copper.) Make and fill a table similar to the accompanying one.

1. Name of specimen.
2. Use.
3. Where found in the United States.
4. Color.
5. Streak.
6. Hardness.
7. Specific gravity. (Do not attempt to find the specific gravity of salt.)
8. Remarks.

If possible, visit one or more of the following places and write an account of what you see: (1) a mine; (2) a smelter; (3) a foundry; (4) a shot tower; (5) a mint; (6) salt works.

NOTE. Apply hydrochloric acid to calcite and describe the result. What other specimen have you had which acts in this way when hydrochloric acid is applied? (See Exercise LII.) Calcite is the essential constituent of this rock, as it is of limestone and marble.

EXERCISE LXIV

LIMESTONE

Describe *coquina* limestone. Tell where it comes from. How do you suppose it was formed? Describe the specimen of *fossiliferous* limestone. Tell where it comes from. Make a drawing of one of the fossils. Give your drawing a title. Draw or describe different varieties of *coral*. Where are corals found? Are they found in sufficiently large quantities to be counted as builders of rocks? (See Fig. 39.) Do you know of other fossils which make limestone? If so, describe or draw them. Limestone has been called the *graveyard of the sea*. What is there in this name which is appropriate? Where is *chalk* found? Describe color, texture, hardness, use.

FIG. 39. A Church built of Coral, at Lahaina, Hawaiian Islands

Distinguish between *chalk* and *crayon*. Test limestone with hydrochloric acid. What mineral have you proved to be present? (See Exercise LXIII.) This mineral is the essential constituent of limestone. Add acid to a very small piece of limestone or to a small quantity of powdered limestone until all effervescence ceases. Does the rock entirely disappear? If not, it is not pure limestone. How do you account for the presence of impurities?

What is limestone used for? What gas is obtained from limestone? How is this gas sometimes used? Apply the acid test to marble. How does marble differ in appearance from limestone? Do you find any fossils in marble? How may fossils disappear from a rock while it is still underground?

EXERCISE LXV

COAL

Examine *peat*. Give color. Make a mental estimate of its specific gravity, and record. Describe the structure of peat. Give a theory of its formation, either your own or that of the books. If your own, give reasons for adhering to this theory; if not your own, state where you got it. Of what value is peat? Where did this specimen come from? Do you know of any near your home?

Examine *coal*. Give color. Estimate specific gravity and compare with that of peat. Do you find any evidence of the existence of vegetable matter in coal? If so, draw one or more forms which you see. Give your drawing a title. How do the books explain the formation of coal? In what parts of the United States is it found? In what part is it found in largest quantities? Name two or three kinds of coal and compare their values for fuel. From what places does your local supply of coal come? Which is considered best? Why?

Describe color, structure, and "feel" of *graphite*. Where is it found? For what is it used? Graphite is made up of carbon.

Carbon is found in both coal and peat. It is also found in the leaves and stems of plants and trees.

Put a piece of peat on a metal plate and heat it slowly over the Bunsen burner. What change in color do you note? The most common color of carbon is black. Peat is often some color other than black because constituents are present other than carbon. The heat drives off these constituents and there remains little but carbon. Why is a charred stick of wood black? Apply heat to the piece of peat until it glows, and allow it to remain

Fig. 40. A Petrified Tree spanning a Gulch in the Petrified Forest of Arizona. (See Topic 98, Fossils, p. 41)

thus for several minutes. What change do you note? What constituent of the atmosphere is probably uniting with the peat? (See Exercise XI.) Carbon is found in all fuel, including kerosene, gasoline, and gas. What constituent of the air unites with it when it burns? This forms carbon dioxide. What do you know about the healthfulness of this gas? Did you ever hear of a person being suffocated from the fumes of a smoldering fire? Why should a gas or oil stove be connected with the flue?

What is the color of the soil in a bog? Where does the coloring matter probably come from? Black slate owes its color to carbon. Pulverize and heat intensely hot a small amount of black slate, thus burning out the carbon. What is the color of the powder which remains? If it is red or brown, what other mineral was probably present in the slate? (See Exercise XI.)

EXERCISE LXVI

GRANITE

Part I

Examine specimens of granite, quartz, feldspar, mica, hornblende. Make and fill a table similar to the following.

1. Name of specimen.
2. Color.
3. Hardness.
4. Structure.
5. Use.
6. Other kinds.
7. Remarks.

How can you distinguish between calcite and quartz? between quartz and feldspar? between feldspar and hornblende? between feldspar and mica? between mica and gypsum of the selenite variety? (Note the elasticity of the flakes.)

When pure feldspar decays it makes a very fine clay called *kaolin*. Examine and describe kaolin. How can you distinguish between kaolin and chalk?

Part II

Examine and describe the surface of a freshly fractured piece of granite. Give color, structure, and components of the piece which you have. Which component is found in greatest abundance? Which least abundantly? Is granite found near your home?

Examine crumbling granite. How many and what components can you discover? How does this specimen differ from solid granite? What component seems to have suffered greatest decay? Put a small amount of highly decomposed granite in water. Which components settle to the bottom? Which component makes the water muddy? Which component is practically indestructible? What becomes of all of the grains of this material when granite decays? Look for small grains of mica in the sand of a flowing stream. Does decomposed granite make good soil? Does decomposed feldspar make good soil?

EXERCISE LXVII

FRAGMENTAL ROCKS

Describe size and shape of the fragments composing *breccia.* These fragments lay at the base of a cliff. Water seeping from the face of the cliff percolated through them. What do you suppose that had to do with the process of cementing the fragments together? Test and name the material forming the cement. Are all the interstices filled? Look closely for crystals.

Examine the pebbles from the beach. Describe size, color, shape. Compare the shape with the shape of the fragments of breccia and account for the difference.

Examine the cementing material between the fragments of the conglomerate. Do you find evidence of the presence of iron in the cement of any of the specimens of conglomerate? If so, what evidence? Test the cement for lime and record the result. Compare the fragments of conglomerate with the pebbles examined above.

Examine and describe color and structure of sandstone. Determine, if possible, of what kind of fragments it is composed. The common cements in sandstone are lime, iron, and clay. In which of your specimens do you find lime as a cement? In which iron? In which clay? In which do you find two kinds of cement present?

Fig. 41. A Young Fir Tree growing from a Crack in a Mass of Granite

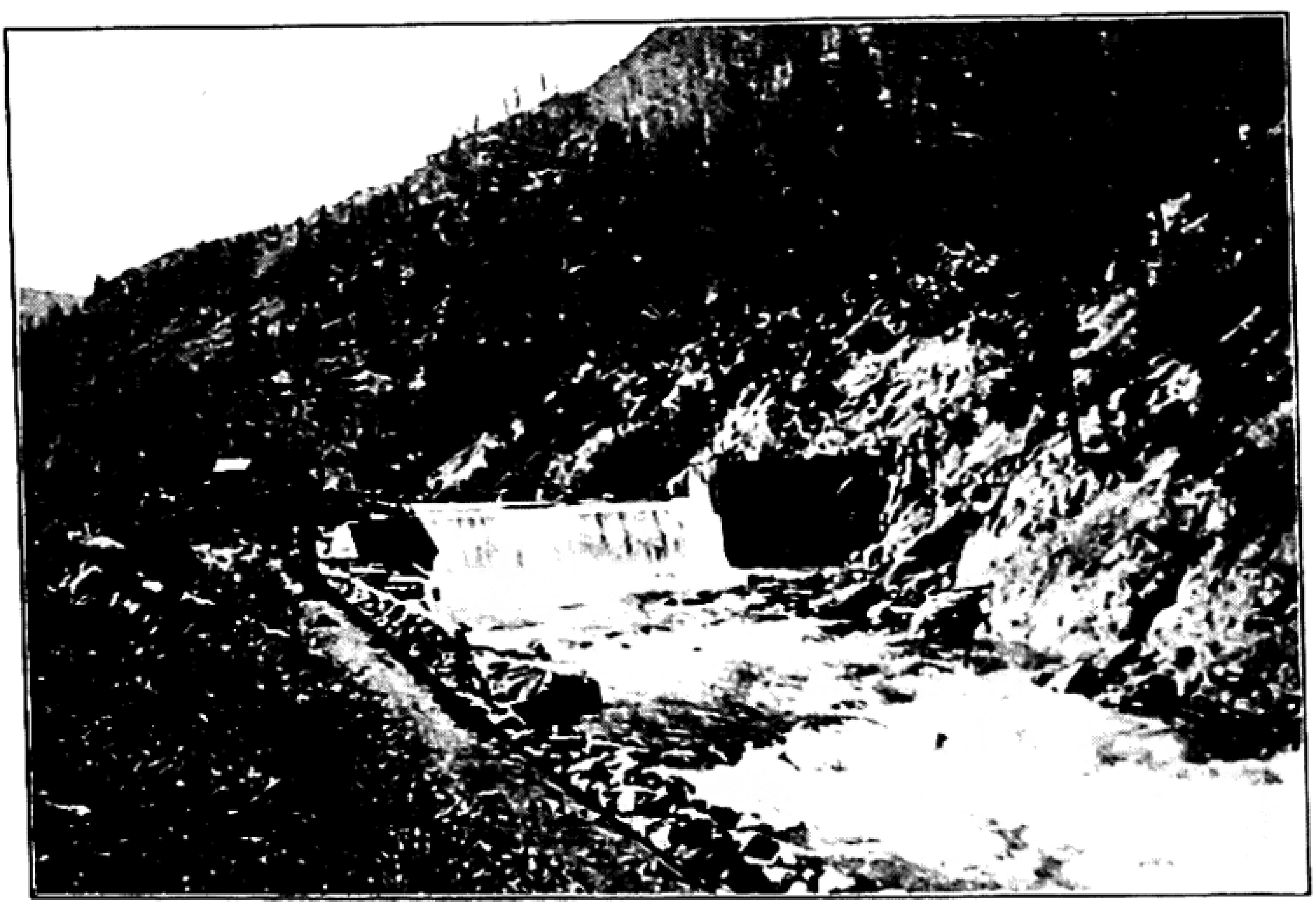

Fig. 42. A Weir on the Truckee River, Nevada, for measuring Water used for Irrigation

Shale is a fragmental rock. Can you readily see the fragments? Account for the color of the specimen which you have. (See Exercise LXV.)

Fragmental rocks are usually built under the water, and the materials of which they are composed are furnished by rivers and by the action of waves. Which of the fragmental rocks

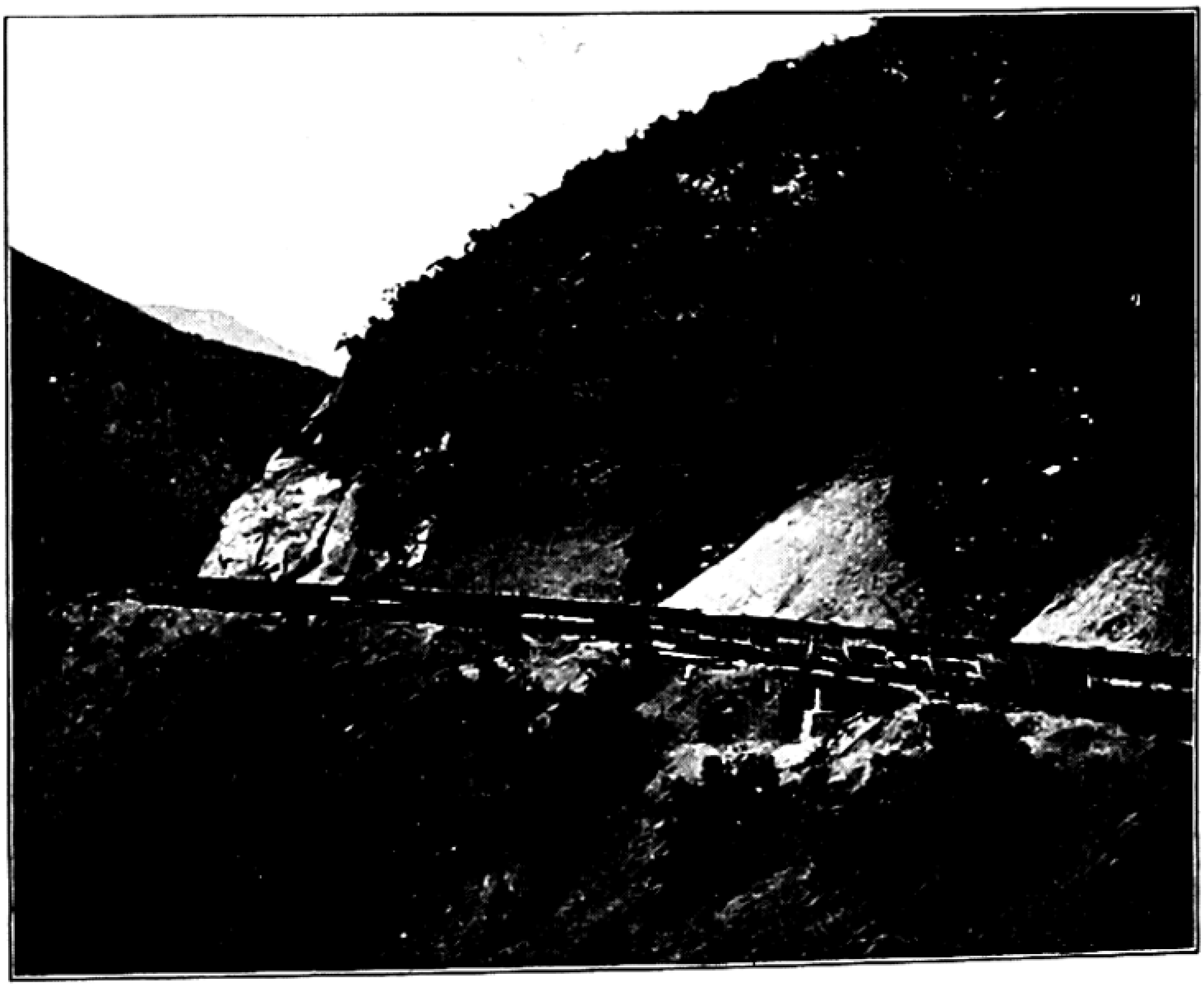

Fig. 43. A Flume near Redlands, California, used for carrying Water for Irrigation from Bear Lake. (See Fig. 21)

would probably be formed nearest the shore? Which is composed of materials that the water would carry farthest before depositing them? Arrange the fragmental rocks in a series, putting that first which was deposited nearest the shore and the others in the order of their deposition.

EXERCISE LXVIII

BUILDING STONE

What kinds of stone are used for building in your vicinity? Which is considered best? Why? Are the same kinds used for foundations? If not, why? What kinds are used for interior decoration? Could these be used for exterior decoration as well? Which of these rocks are quarried or obtained near your home? Where do the others come from?

How is slate used in building? Could granite be used for the same purpose? Give reason for your answer. If blocks of stratified rocks were to be used in a wall, should they be placed with the layers horizontal or vertical? Why?

Did you ever see an old stone building with the surfaces of the stones crumbling? Why do they crumble? What kind of building stone crumbles least? Why? Is a dry or a moist climate more favorable for the preservation of a stone building? Do vines clinging to the surface of a stone wall cause the wall to weather more or less rapidly than it otherwise would?

Examine the following rocks: granite, red sandstone, gray sandstone, limestone, marble, slate. Make and fill a table similar to the following. (In addition to your observations, seek information from property owners, contractors, stone masons, and others.)

1. Name of stone.
2. Color.
3. Ease with which it can be worked.
4. Durability.
5. Use.
6. Source of local supply
7. Remarks.

EXERCISE LXIX

DECOMPOSING AGENTS

Part I

What effect does heat have upon brass and iron? (See Exercise XXXI.) To ascertain whether they are equally affected, heat a bar consisting of one brass plate and one iron plate. What change of shape do you observe? Which plate expands more upon being heated? Feldspar and quartz expand unequally when heated. What effect will change of temperature probably have upon the texture of granite? Will a granite monument endure longer in a climate of uniform or changeable temperature?

Part II

Examine granite having a growth of lichens on the surface. Which would dry more quickly if thoroughly wet, a piece of granite with a covering of lichens or a piece without lichens? (If in doubt, try it.) How will this affect the rate of weathering of granite? How do lichens cling to the granite? Will this aid or retard weathering? The decay of the roots makes an acid which the water carries into the granite. Will the presence of this acid aid or retard weathering?

Part III

Write a paper telling how each of the following aids in the process of rock decay.

1. Oxidation. (See Exercise XI.)
2. Vegetation and roots.
3. Burrowing animals.
4. Water. (See Exercise LII.)
5. Rivers, waves, glaciers. (See Exercises XXXII and LIX.)

EXERCISE LXX

IRRIGATION

Write a paper on one or more of the following phases of irrigation.

1. Irrigation in the United States.
2. Extent of irrigation.
3. Antiquity of irrigation.
4. Methods of elevating water for irrigation.
5. Methods of storing water for irrigation.
6. Methods of distributing water for irrigation.
7. Methods of measuring water for irrigation.
8. Losses of water in irrigation.

(State books read and authorities consulted in writing your paper.)

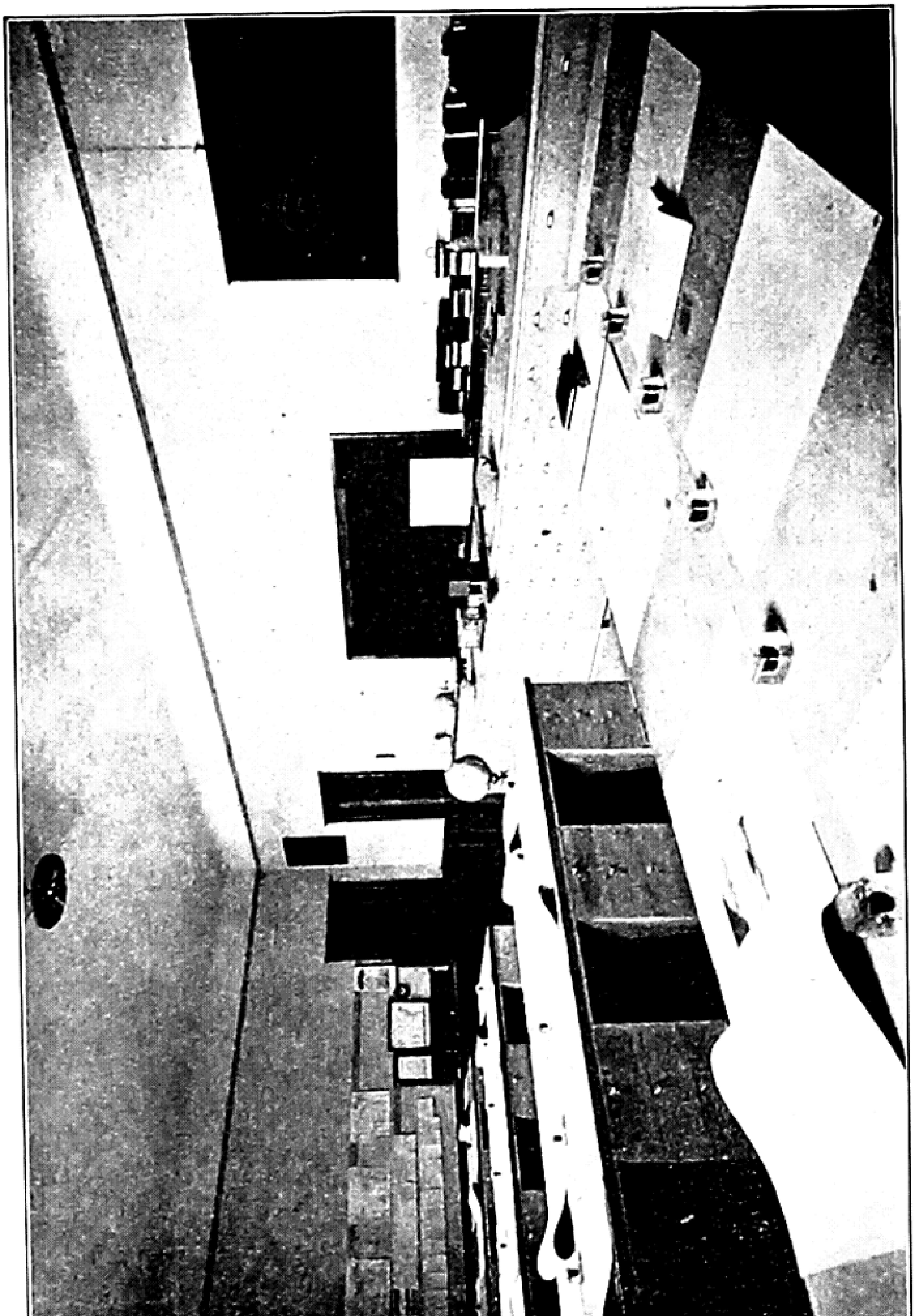

FIG. 44. A Laboratory for Physical Geography

Union High School, Redlands, California

APPENDIX

LIST OF TEXT-BOOKS

Davis, *Physical Geography.* Ginn & Company. 1899.

Davis, *Elementary Physical Geography.* Ginn & Company. 1902.

Dryer, *Lessons in Physical Geography.* American Book Company. 1901.

Gilbert and Brigham, *An Introduction to Physical Geography.* D. Appleton & Co. 1902.

Redway, *Elementary Physical Geography.* Charles Scribner's Sons. 1900.

Tarr, *New Physical Geography.* The Macmillan Company. 1904.

LIST OF REFERENCE BOOKS

Bailey, *Principles of Agriculture.* Macmillan. $1.25.

Beal, *Seed Dispersal.* Ginn. 50 cents.

Bergen, *Foundations of Botany.* Ginn. $1.50.

Brigham, *Geographic Influences in American History.* Ginn. $1.75.

California Water and Forest Association, *Should the Forests be Preserved?* California Water and Forest Association, Mills Building, San Francisco. Free.

Coulter, *Plant Studies.* Appleton. $1.25.

Crosby, *Common Minerals and Rocks.* Heath. 40 cents.

Davis, *Elementary Meteorology.* Ginn. $2.50.

Dodge, *A Reader in Physical Geography for Beginners.* Longmans. 70 cents.

Fairbanks, *Rocks and Minerals.* Educational Publishing Company. 60 cents.

Fairbanks, *Western United States.* Heath. 60 cents.

Garriott, *Long-Range Weather Forecasts.* Bulletin No. 322, United States Weather Bureau.

Gifford, *Practical Forestry.* Appleton. $1.00.

Harrington, *About the Weather.* Appleton. 60 cents.

Heilprin, *The Earth and Its Story.* Silver. $1.00.

Jordan, *Science Sketches.* McClurg. $1.50.

Jordan and Kellogg, *Animal Life.* Appleton. $1.20.

Kenealy, *Weather Bureau Stations and their Duties.* United States Weather Bureau. Free.

King, *Irrigation and Drainage.* Macmillan. $1.50.

King, *The Soil.* Macmillan. 75 cents.

Kinney, *Forest and Water.* Post Publishing Company, Los Angeles. $1.50.

Mead, *Irrigation Institutions.* Macmillan. $1.25.

Merriam, *Life Zones, and Crop Zones of the United States.* Bulletin No. 10, United States Biological Survey. Free.

Moore, *Bacteria and the Nitrogen Problem.* Reprint from *Year Book* of the United States Department of Agriculture for 1902. Free.

Moore, *Climate, Its Physical Basis and Controlling Factors.* Bulletin No. 34, United States Department of Agriculture. (Weather Bureau.) Free.

Muir, *Mountains of California.* Century Company. $1.50.

Newcomb, *Elements of Astronomy.* American Book Company. $1.00.

Osterhout, *Experiments with Plants.* Macmillan. $1.25.

Pinchot, *Primer of Forestry,* Parts I and II. Bulletin No. 24, Parts I and II, United States Bureau of Forestry. Free.

Roth, *A First Book of Forestry.* Ginn. 75 cents.

Russell, *Glaciers of North America.* Ginn. $2.00.

Russell, *Lakes of North America.* Macmillan. $1.50.

Russell, *North America.* Appleton. $2.50.

Russell, *Rivers of North America.* Putnam. $2.00.

Russell, *Volcanoes of North America.* Macmillan. $4.00.

Shaler, *Aspects of the Earth.* Scribner. $2.50.

Shaler, *First Book in Geology.* Heath. 45 cents.

Shaler, *Outlines of the Earth's History.* Appleton. $1.75.

Shaler, *Sea and Land.* Scribner. $2.50.

Shaler, *Story of Our Continent.* Ginn. 75 cents.

Tarr, *Economic Geology of the United States*. Macmillan. $3.50.

Tarr, *Elementary Geology*. Macmillan. $1.40.

Toumey, *Relation of Forests to Stream Flow*. Reprint from *Year Book* of the United States Department of Agriculture for 1903. Free.

Waldo, *Elementary Meteorology*. American Book Company. $1.50.

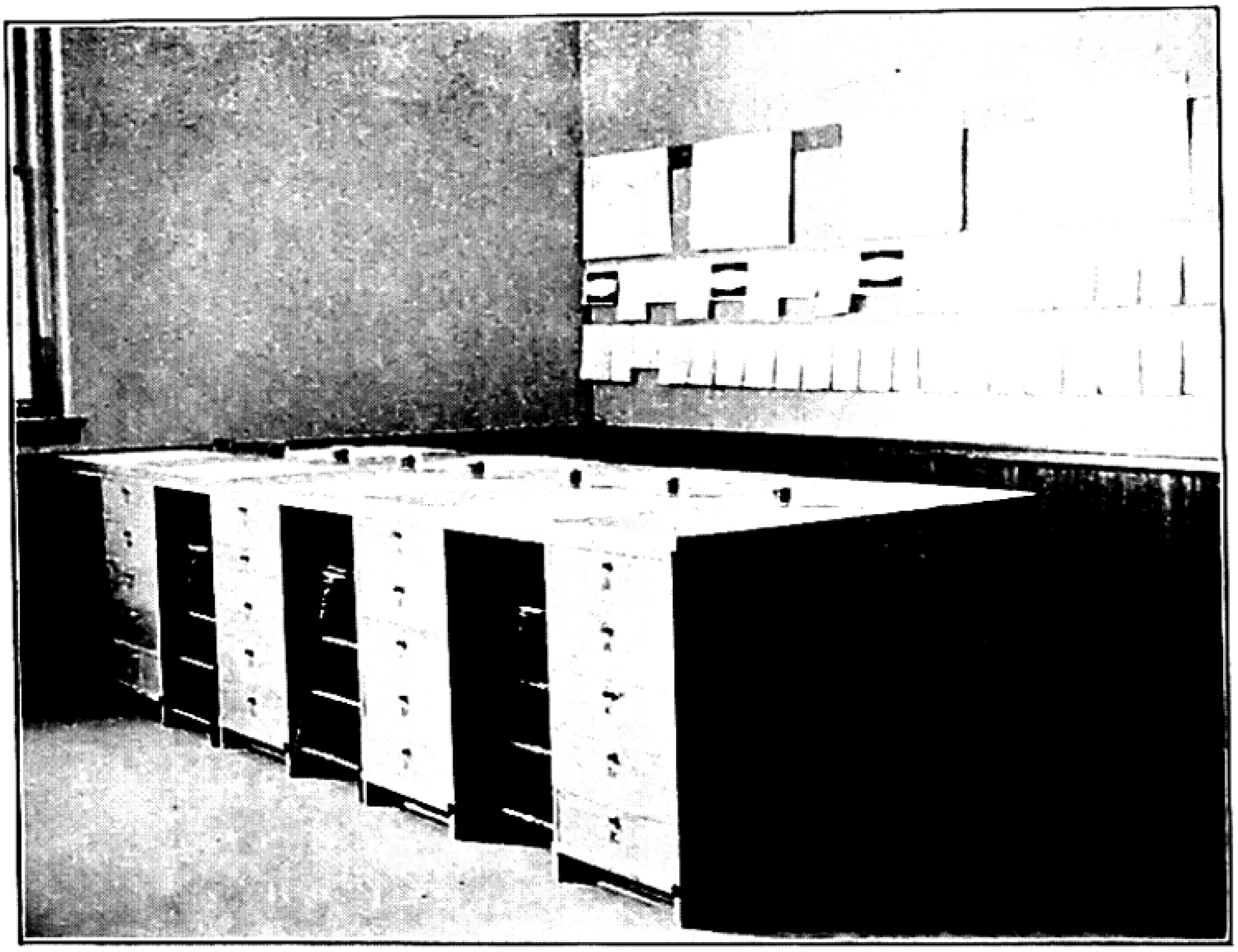

FIG. 45. Pupils' Work Table in the Laboratory

Height, 36 inches; width, 48 inches; length, 12 feet. Knee space, 18 inches wide; stool, 24 inches in height

Ward, *Report on the Petrified Forests of Arizona*. United States Department of the Interior.

Westgate, *Reclamation of Cape Cod Sand Dunes*. Bulletin No. 65, United States Department of Agriculture. (Bureau of Plant Industry.)

Winchell, *Walks and Talks in the Geological Field*. Jacobs. $1.00.

Winslow, *Principles of Agriculture*. American Book Company. 60 cents.

Young, *Lessons in Astronomy*. Ginn. $1.25.

LIST OF GOVERNMENT MAPS

Topographic Atlas, United States Geological Survey, Folio No. 1; 25 cents. Same, Folio No. 2; 25 cents.

Canyon (Wyo.) sheet, topographic map of the United States Geological Survey; 3 cents wholesale.[1]

Doylestown (Penn.) sheet, topographic map of the United States Geological Survey; 3 cents.

Assembled topographic sheets, showing plateau and divides of the Yellowstone National Park, Wyoming, as follows: Gallatin, Canyon, Shoshone, Lake; 4 sheets, 3 cents each.

Assembled topographic sheets, showing Green Bay (Wis.) lobe of ancient glacier as follows: Madison, Sun Prairie, Waterloo, Watertown, Oconomowoc, Waukesha, Milwaukee, Evansville, Stoughton, Koshkonong, Whitewater, Eagle, Muskego, Bay View, Brodhead, Janesville, Shopiere, Delavan, Geneva, Silver Lake, Racine; 21 sheets, 3 cents each.

Assembled topographic sheets, showing barrier beaches off the coast of New Jersey, as follows: Sandy Hook, Asbury Park, Barnegat, Long Beach, Little Egg Harbor, Atlantic City; 6 sheets, 6 cents each.

Assembled topographic sheets, showing Cape Cod (Mass.), as follows: Provincetown, Wellfleet, Chatham, Yarmouth; 4 sheets, 3 cents each.

Pilot charts of the North Atlantic ocean, United States Coast and Geodetic Survey; 10 cents each. Same, North Pacific ocean; 10 cents each.

Tide Tables for Pacific (or Atlantic) ports for current year, United States Coast and Geodetic Survey; 10 cents.

Map showing magnetic declination in the United States, United States Coast and Geodetic Survey.

United States Coast and Geodetic Survey maps (50 cents each), as follows:

[1] The Geological Survey uses the term *wholesale* to include lots of one hundred or more maps purchased at one time. The wholesale price of topographic maps is given in each case. Single maps cost 5 cents.

109 Boston bay.
110 Cape Cod bay.
120 New York bay.
194 and 195 Mississippi river to New Orleans.
5100 San Diego to Santa Monica.
5581 San Francisco entrance.

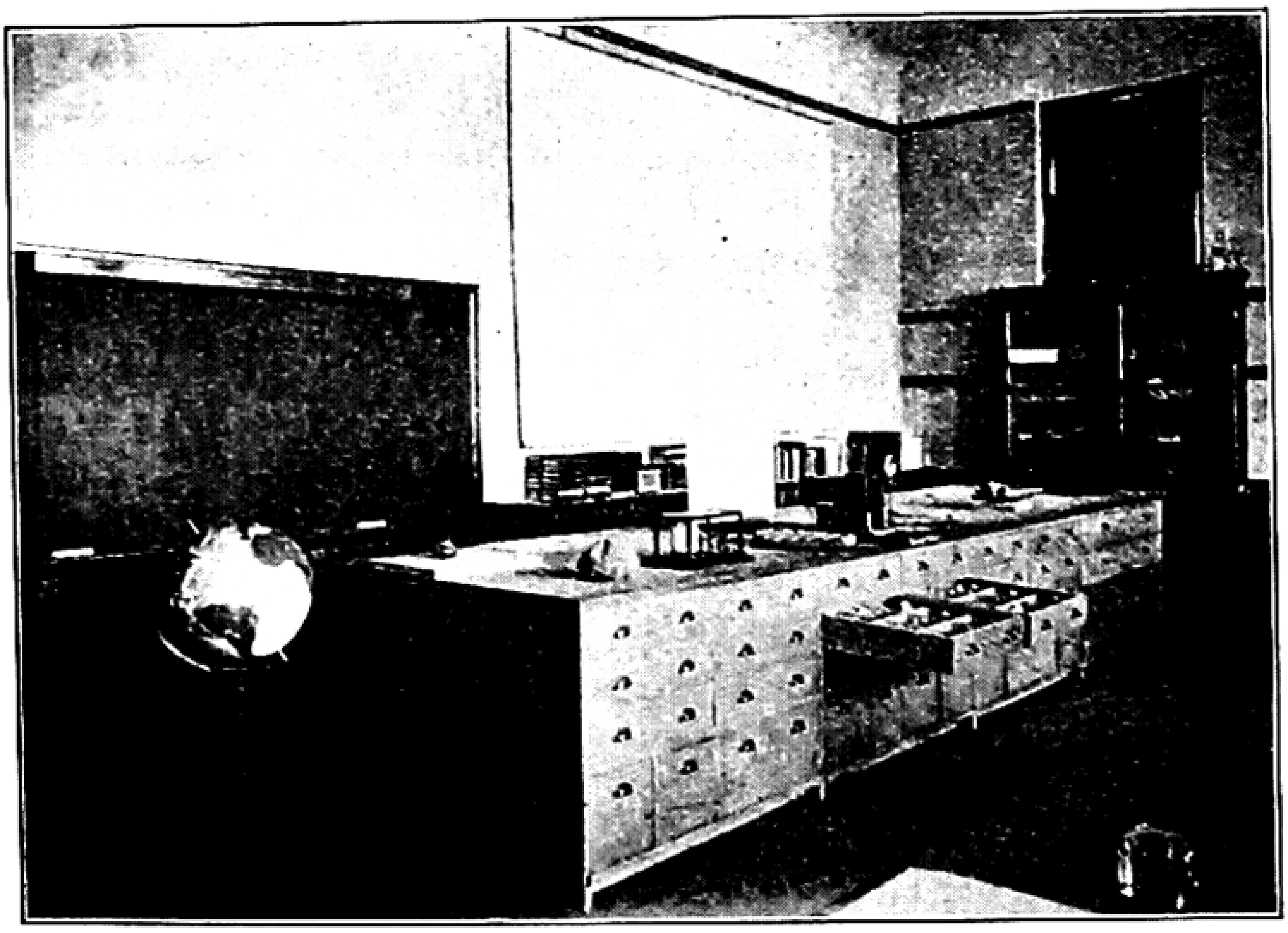

FIG. 46. Teacher's Cabinet Table in the Laboratory

Large drawers at the right, to receive large maps lying flat, 48 × 48 × 6 inches; upper drawers at the left, to receive topographic maps (with partitions for mineral and other specimens), 22 × 22 × 5 inches; lower drawers at the left, to receive larger specimens and the smaller pieces of apparatus, 22 × 10 × 10 inches

Weather Bureau publications, as follows:

Daily weather map from Washington; free.

Daily weather map from local station; free.

Average annual precipitation in the United States (with maps), a reprint from the *Monthly Weather Review* for April, 1902.

Wall map of the United States, United States Department of the Interior; $1.00.

LIST OF APPARATUS AND SUPPLIES

NOTE. This list includes only such apparatus and supplies as are specifically referred to in Part II of this manual. It will be observed that a large part is probably already in the possession of the average high school, and, if necessary, the teacher of physical geography can draw upon the departments of physics, chemistry, mathematics, and geology for these things.

Gyroscope (may be homemade), 8-inch globe with movable meridian, pasteboard circle to fit globe, wet and dry bulb thermometer, maximum and minimum thermometer, barometer, rain gauge, slated globe.

Rotating machine with brass rings, specific-gravity balances and box of weights, Bunsen burner, blowpipe, air pump, apparatus and materials for generating oxygen, same for generating carbon dioxide, pneumatic trough, steel wool, watch crystals, ether, alcohol, triangular glass prism, bar magnet, mounted magnetic needle, Torricellian tubes, mercury, test tubes, beaker, rubber stoppers, glass tubing, adjustable pinchcock, mortar and pestle, evaporating dish, funnel, filter paper, hydrochloric acid, apparatus for distilling water, hydrometer.

Lead bullet, string, old electric-light bulb, empty bottles, candle, corks, tumbler with straight sides, V-shaped trough, teakettle, yardstick, brightly polished metal cup, ice, glass jar with straight sides, soap, mirror, box of tacks, blocks of wood, pointer, sand, lever with wire and rubber band, salt, clay, sand, gravel, alum, photographers' hypo, sea water.

Mineral and rock specimens, about forty different kinds, sufficient in number to supply pupils of largest class when working in pairs.

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NOTEBOOK

INSTRUCTIONS TO PUPILS

Make a neat, clean-looking page.

Answer all questions, making complete sentences.

Do what you are asked to do and state in writing what you did. Your sentences should not be imperative.

Do not hesitate to use the pronouns *I* and *we* when necessary. In class experiments the impersonal form is generally preferable.

Make as many paragraphs in your written notes as there are in the printed instructions.

Your notes should be an exposition of the subject treated, so that they will make clear reading without reference to the printed instructions.

In general, statements of what you did should be in the past tense; statements of scientific or general truths, in the present tense.

Outline Map of United States
Cities and towns shown represent stations of the United States Weather Bureau

Outline Map of United States

Cities and towns shown represent stations of the United States Weather Bureau

Outline Map o... ed States

Cities and towns shown represent statio... e United States Weather Bureau

Outline Map of ... States

Cities and towns shown represent station[s of the] United States Weather Bureau

Outline Map of United States

Cities and towns shown represent stations of the United States Weather Bureau